CSR Kompetenzzentrum Textil & Bekleidung Niederrhein

Masterarbeit

„A T-shirt in circular economy: Challenges and means to the possible solutions by assessing fibre, chemical and plastic packaging“

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A T-shirt in circular economy: Challenges and means to the possible solutions by assessing fibre, chemical and plastic packaging

Thesis for the academic degree “Master of Science”

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Date of submission:

08.03.2021

Summer Semester, 2021

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Abstract

Textile companies are trying to move towards a more circular business model with the aim of benefiting businesses as well as mitigating significant environmental damages and climate changes caused by clothing production, consumption and waste generation. Taking the current scenario into account, The primary goal of this research was to discover and analyze the existing challenges that companies are facing, including the challenges related to maintaining material quality as well as technical and infrastructural limitations in pursuing the circular economy approach. This paper also attempted to explore possible means to overcome the difficulties by exploring sustainable options in raw materials selection and more systemic approaches which may have good potential to shift towards a circular economy. Subsequently, the report is outlined by defining certain proposals for a product base in order to support the transition to a circular economy.

1. Introduction

A large number of people, including myself, tend to purchase more cloths than we actually require and when our T-shirt costs less, we usually do not hesitate to throw it out just because it is discoloured, or it is not bright anymore. Every year, an estimated 26 billion pounds of textiles and cloths are thrown away in landfills.[1] Based on the forecast from the "Global Fashion Agenda" as well as the "Boston Consulting Group", if this waste generation continues, then the clothing waste will reach 148 million tonnes by 2030.[2] McKinsey research presents that the global clothing sector is responsible for greenhouse gas release of around 2.1 billion metric tonnes in 2018.[3]

A circular economy in the textile industry portrays a mechanical framework that produces neither waste nor contamination with the help of renovating materials to circulate inside the production and utilization framework for as far as it might be feasible, then it leads these materials back into the biosphere to recover the normal capital.[4] But, instead of following this model, over the many years with the help of industrialization, we humans adopted the traditional linear approach: we take, we make and we dispose.[5] Even though the circular economy movement already started, but the global economy could only achieve 8.6% circularity so far.[6]

Over half a century ago, Kenneth E. Boulding in his monumental paper, "The Economics of the Coming Spaceship Earth" attempted to demonstrate these two models metaphorically. In that paper, the "Cowboy economy" was mentioned as our current industrial (open) economy which behaves as if we have unlimited resources, on the other hand, "spaceman economy" as a more closed economy where the earth will be a single spaceship with limited reserves.[7] Therefore, to benefit business, economy, society and most importantly the environment, the new

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[1] Cf. Online: Goldberg (2016)
[2] Cf. Online: PULSE OF THE FASHION INDUSTRY (2017)
[3] Cf. Online: Fashion on climate (2020)
[4] Cf. Online: Deutsche Gesellschaft für Internationale Zusammenarbeit-GIZ (2019)
[5] Ibid.
[6] Cf. Online: Circle Economy (2020)
[7] Cf. Online: Boulding (1966)

economic system – the circular economy has been introduced. Its intention is to solve both environmental problems and problems associated with the economic process.[8] Circular economy responses to a basic question: How we will keep most of the lost value in our conventional system and within this concept, we try and notice ways in which to make loops in this linear model to hold that value.[9] The textile and clothing sectors are the key focuses of the circular economy.

1.1. Objective

With regards to the circular economy, we have to be planning for core raw materials, for example, fibres, colours, chemicals and plastics for packaging that are durable, contain no harmful substances and can be additionally handled in cycles after consumption. Having these in mind, the main motivation of this project comes to investigate the current difficulties and possible ways to overcome these difficulties with available possible techniques to avail textile industry with the circular economy with a particular focus on a basic complete T-shirt's raw materials. Because there are still challenges in designing and selecting materials for even a basic garment. For example, the consumption of man-made cellulose fibres like 'viscose' and 'lyocell' has grown significantly in recent years.[10] Two-thirds of this amount are created from petrochemical raw material like polyester and polyamide where cotton is one-fifth of it.[11] At the same time, even though plastic packaging, especially polybags still make up a relatively small amount of the total effect of a garment lifecycle, there is a growing focus on the reduction of it. Therefore, these raw materials should be the key issues to focus on in order to get this unsustainable industry transitioned to a circular economy. Simultaneously, there will be attention paid to figure out the potential available sources that may have the ability to reduce the difficulties that concerned parties are facing to get the circular economy model into their business. To fulfill the objective of the research project below questions ought to be answered.

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[8] Cf. Online: Ellen MacArthur Foundation (n.d)
[9] Cf. Online: McKinsey (2016)
[10] Cf. Online: Goswami & O'Haire (2016)
[11] Cf. Online: Climate-kic (n.d)

- What are the current challenges to bring a “Basic T-shirt” back into the circular economy?
- What are the current as well as the best possible means to overcome the challenges in applying the circular economy approach?
    - What approaches should be taken to promote the circular economy in reducing toxicity impact from textile chemicals?
    - What sustainable material options are available?

This paper will not only explain the challenges and solutions but also will help to understand how the different life cycles of raw materials act in the circular economy concept. The field of the circular economy is extremely wide and this paper will simply have the option to work on a fraction of it.

1.2. Methodology

As the textile industry is considered the second most polluting industry on the earth, this research will focus on it.[12] To carry out the objectives, this research paper will start with some background. Then it will analyze the current key challenges and challenges for a circular economy in the clothing industry as well as on the environment and society taking a product model into consideration. Then it will analyze various measures that are available and being practiced in this industry to contribute to the circular economy. Various organizations have been examined concerning their plan of action towards the circular economy. To obtain the necessary information, this paper utilized online company information as well as inputs from literatures review.

2. Background

The current society with progressive awareness about ecological circumstances and limited resources play significant functions in incorporating sustainable and socially responsible business models in the decision choice of organizations.[13] This paper goes on the horizon discussing the background of circular economy

[12] Cf. Online: United Nations (2019)
[13] Cf. Online: Müller & Pfleger (2014)

which is a necessity to understand the growing world with economic development by saving resources.

2.1. Linear economy

For a better insight of the concept of the circular economy, it is essential to have some fundamental information as to our current linear economic model. The expression “linear economy” is actually being used as the counterpoint of the circular economy.[14] That is the reason, in several publications, both models are mentioned together to distinguish between these competing ideas; one as highly effective but unsustainable, that is the linear economy and another one is highly efficient and also sustainable; which is the circular economy.[15] Suppose, there are boundless materials and then the linear model would work efficiently without affecting the environment; unfortunately, it has been realized that it is not sustainable, as materials are limited and they are getting scarce and has negative consequences for our world. The textiles industry depends on non-renewable resources which include oil, chemicals, fertilizers and so forth. This sector additionally uses around 93 billion cubic meters of water yearly which adds issues in some water-scarce areas.[16] Because of its low rates of usage and low levels of recycling, the current economy is having tremendous pressure on resources.[17] In this linear economy, we are extracting raw materials from nature, transforming them to obtain end-products and then throwing them away which leads to waste too.[18]

2.2. Circular economy

Our current activities have big effects on the deterioration of the socio-ecological environment and since the linear industrial model of today can be seen as a primary driver of this problem, it suggests a need for a model that is more consistent with the cyclical nature of our dynamic planet. A circular economy is an idea that seeks to have such a model. It can be said, that the idea of circularity is

[14] Cf. Online: Geodis (2018)
[15] Cf. Online: Sillanpää & Necibi (2019)
[16] Cf. Online: The conscious challenge (2019)
[17] Cf. Online: Ellen MacArthur Foundation (2017)
[18] Cf. Online: Ellen MacArthur Foundation (n.d)

as old as time itself since it is always active in this way in our world; as natural material has always been produced and reproduced ever since life first appeared on the Earth.[19] Due to a circular biological process, nothing is wasted by forming a continuous cycle but in the last 200 years due to the industrial revolution, we started operating according to a linear model which in turn causing problems.[20] The transformation to a circular economy could return us to where we started as well as arrange our economy in such a way that reflects nature. According to a study, carbon dioxide (CO_2) emissions could be reduced by adopting the circular economy; also, it has the potential to create additional jobs in the future.[21] This development strategy involves a structured and modernized transformation of production processes and patterns of consumption, systemic changes and innovations in economic growth without increasing the utilization of energy; it is such an economy where the value of products and materials is maintained as long as possible.[22] The most accepted definition of circular economy has been introduced by the Ellen MacArthur Foundation as a restorative or regenerative economy by intention and design.[23]

The circular economy relies on the following three fundamental principles given by Ellen MacArthur Foundation:[24]

Principle 1: Improve and maintain natural capital by managing limited resources and balancing flows of renewable resources.
Principle 2: Optimize resource yields by distributing products and materials with their maximum value.
Principle 3: Encourage the efficiency of the frameworks by identifying and disposing of negative variables from the design.

[19] Cf. Online: PWC (2019)
[20] Ibid.
[21] Cf. Online: Wijkman & Skånberg (2020)
[22] Cf. Online: European commission (2014)
[23] Cf. Online: Ellen MacArthur Foundation (2013)
[24] Ibid., 4.

2.2.1. Origins and concepts

Even though it is not possible to trace a single root, date or author of a circular economy concept, there is evidence that this theory has been picking up interest since the late 1970s.[25] There are some authors, like Andersen, Ghisellini who contributed more to this concept by showing how our natural resources attributed their support towards the economy by supplying inputs for production including acting as a sink for waste.[26] However, the major boost in the advancement of this concept was attributed to the economic study of the Ellen MacArthur Foundation in 2012, which included the circular economy concept; this organization researched theories like “Cradle to Cradle”, “Biomimicry” and “Industrial Ecology” that seek to provide solutions for environmental degradation and unregulated aggressive consumption growth.[27] There are other major schools of thought which include the “Cradle to Cradle” design ideology of William McDonough and Michael Braungart; this term also used by economists David W. Pearce and R. Kerry Turner in 1990; and the “blue economy” approach by Gunter Pauli to connect and combine disparate environmental problems. There are two more terms often used within the field of the circular economy are mentioned below.

I. Recycling: Upcycling and downcycling

It is possible to consider recycling as an umbrella term for upcycling and downcycling. Upcycling is a mechanism in which, in their second life, recycled materials are transformed into an object of greater worth and It is accepted as an assuring way of reducing the use of resources and creating sustainable consumption.[28] On the other hand, downcycling is a way of tearing down a product to its raw content and creating a new product, typically of lower quality than the initial product; in other words, making something of less value out of a product of greater quality.

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[25] Cf. Online: Ellen MacArthur Foundation (2015)
[26] Cf. Online: The Circular Economy (2018)
[27] Cf. Online: Mentink (2020)
[28] Cf. Online: Sung (2015)

II. The waste hierarchy

The Waste hierarchy is an instrument used in the assessment of processes that preserve the environment alongside energy and resource consumption.[29] The hierarchy determines desired program goals based on sustainability.[30] Below figure 1 illustrates a common waste hierarchy going from most favorable to least favorable actions.

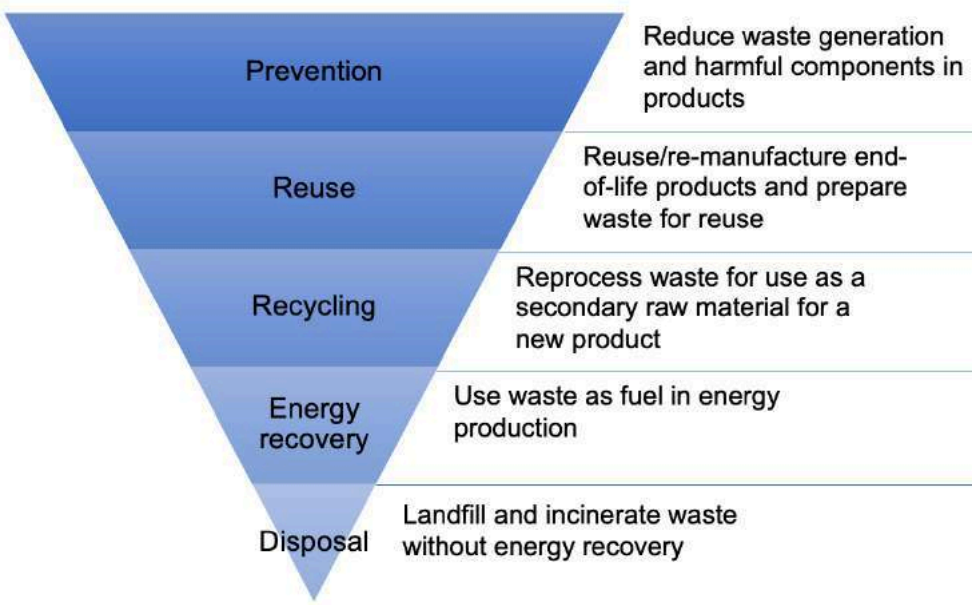

Figure 1: The waste hierarchy

(Source: Adapted from "Organisation for Economic Co-operation and Development-OECD", 2020)

3. Circularity in the clothing industry

People have become more aware of the clothing industry's environmental consequences in recent years, forcing manufacturers, retailers and brands to reduce their environmental footprint. Since this industry is one of the biggest polluting industry, it is high time to adopt durable, high quality and designed based cloths which could be incorporated with a business model to withdraw from the take-make-dispose linear system. In the circular economy, clothing is not being discarded fully and since resources can be used repeatedly, they usually keep their value in the clothing chain. Fashionable, vintage, high-quality and fibre collection for recycling are some of the ways to flourish more towards this system.

[29] Cf. Online: Hansen, Christopher, & Verbuecheln (2002)
[30] Ibid.

To be circular, it is also important, that the whole supply chain of the clothing industry needs to be modified by changing the way products are designed, manufactured, consumed as well as the way businesses are conducted. Moreover, to be more precise, circularity in clothing is not only about just recycling, but it is also about achieving original value by increasing utilization in every step of the life cycle.[31] In below figure 2, circularity is shown as taking every step into consideration.

Figure 2: Circularity in the clothing industry
(Source: Adapted from "The European Apparel and Textile Confederation, 2020" and "European Clothing Action Plan, 2019")

3.1. Circularity in fibre

Clothing is a lifelong item in our daily life. Millions of people are buying cloths but without thinking regarding the aftermaths. Clothing production has also been multiplied in the last 15 years and the number of wears has been decreased by 36% per garment.[32] This is truly not a circular way. Thus, this natural aftermath of the existing trends of production and use of clothing is increasing the demand for fibres creating swelling volumes of waste in return.[33] With a variety of raw materials, trims and accessories, a T-shirt can be made and packed for end users, which have to be processed before recycling. Therefore, it is important to know

[31] Cf. Online: PWC (2018)
[32] Ibid., 4.
[33] Cf. Online: Circle Economy (2017)

how many types of material like fibre from a T-shirt can be recycled before it losses its ability to be transformed into new fibre or yarn. simultaneously, natural fibre materials are being blended and twisted with synthetic fibres making the recycling process more complicated. Considering a circular approach industry can collect that waste, tear or melt it down into polymer and reconstruct it up to a new fibre which would be the vital action for reducing the effect of textile industry.

3.2. Circularity in Chemical

It is possible to describe nearly any substance on this planet as chemical, from rivers to streams, gold and even sugar. But, industrially produced chemical compounds are referred to here which are originated in a laboratory or through some sort of industrial process. The chemistry is intimately linked to the textile industry. More than 8000 different chemicals are known to be used by the textile industry for various types of purposes.[34] The significant concern here is the use and release of toxic chemicals from fibre and clothing production, which is leading to health and environmental impact caused by the emissions of these chemicals. Hazardous chemicals in the waste can obstruct progress toward a circular economy.[35] It should be ensured that chemicals especially hazardous ones are properly recycled but on the other hand, recycling chemicals would be easier if clothing is produced without hazardous chemicals in the first place.[36] The overall objective should be to assess and remove hazardous chemicals from the total value chain as much as feasible, discover ways to recover or recycle the chemicals and find out harmless substitutes that can bring the same properties in the product.[37]

Chemicals have various types of functions in a large number of different types of operations in textile manufacturing. Despite the fact that the textile industry uses a large number of chemicals, it is necessary, and it should be possible to categorise these chemicals based on their functions. [38] And, since chemicals are at the heart

[34] Cf. Online: Scott (2015)
[35] Cf. Online: European Commission (2020)
[36] Cf. Online: European Chemicals Agency – ECHA (n.d)
[37] Ibid., 5.
[38] Cf. Online: Roos (2015)

of the circular economy,[39] categorising the chemicals may help to understand and manage these chemicals as well as eventually, achieve circular economy principles. The major categories are as follows:[40]

i. Functional chemicals: Chemicals that are either man-made or derived from nature and have specific functions.
ii. Residues from the production process: Chemicals that are either man-made or derived from nature and do not have any functionalities in the final product.
iii. Impurities: Chemicals that are produced unintentionally by humans or nature.

3.3. Circularity in plastic packaging

Plastic is inseparably connected to industrial pollutions, carbon dioxide (CO_2) emissions and other concerns; the problem is not necessarily with plastic, it is with the way industry is dealing with it. Plastic is light, takes less energy to produce and transport. But the waste produced by the use of plastic that only stops at the end in the oceans or landfill sites is creating problems. It is predicted that plastic waste will surpass the total weight of fish in the sea by 2050.[41] This plastic problem is rising noticeably even more in the current pandemic situation; we are shopping the cloths including other supplies online which is causing more stacked up plastic packaging than ever these days. Getting this valuable material usage in the circular economy practice should be a wise decision where it is possible to reuse, recycle or even compost it.

Polyethylene or polythene (PE) is the most commonly used plastic, a mixture of similar polymers of ethylene. There are many varieties of polyethylene, but “low-density polyethylene (LDPE)”, “linear low-density polyethylene (LLDPE)” and “High-density polyethylene (HDPE)" are the most important ones.[42] LDPE is flexible and tough; LLDPE is very flexible, has higher tensile strength, impact

[39] Cf. Online: European Chemicals Agency – ECHA (2016)
[40] Ibid.
[41] Cf. Online: World Economic Forum, Ellen MacArthur Foundation, & McKinsey (2016)
[42] Cf. Online: Manjula et al. (2017)

resistance; HDPE is more hard and has higher tensile strength than LDPE.[43] While considering plastic packaging or polybag in the clothing industry, most of the polybags are made of LDPE[44] and to some extent the LLDPE. In the fashion industry, the use of plastic bags is everywhere, about 180 billion of which are made annually for packaging, transporting and protecting cloths and other fashion items; unfortunately, only around 15 percent of all polybags are obtained for recycling.[45] Now, recycling is just one option for these plastic waste issues, there are other alternatives, for example, reusing, energy recovery by incineration or use of degradable, biodegradable or compostable plastic bags. Some brief descriptions of each term are given below to comprehend the differences among them.

a) Reusable Packaging

There is a growing emphasis on the benefits of reusable packaging, but there is still a potential gap among end-customers, retailers and clothing manufacturers due to the lack of returnable solutions at a large scale. Achieving high returns of plastic packaging from customers is a challenge, at the same time, sending these plastic polybags back to the clothing manufacturing sites covering long distances may not be much practical solution to most retailers.[46]

b) Recyclable Packaging

As a sustainability practice, the most typically used form of packaging is recyclable packaging these days; Usually, the collected plastic waste is separated mechanically and/or manually into different plastic forms and then extruded and pelletized to be molded to be new recycled plastic polybags.[47]

c) Degradable Packaging

Degradable plastic bags are produced from plastic with other additives used to break the plastic down over time when exposed to external stimuli for example

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[43] Cf. Online: PlasticsEurope (n.d)
[44] Cf. Online: Wright (2020)
[45] Cf. Online: Fashion for Good (2019)
[46] Ibid., 10.
[47] Cf. Online: TERRACYCLE (n.d)

sunlight.[48] Different forms of degradable plastics are currently available; each responds to the disposal environment differently and degrades by different mechanisms. It is possible to categorize degradable plastic into two ways:[49]

I. Depending on the degradation way; for example, whether they need heat, ultraviolet light, mechanical stress or water to break down or whether they need microorganisms to degrade, i.e., Oxo-biodegradable, Photodegradable, Compostable, Biodegradable, etc.
II. Depending on the material source; for example, whether they are produced from natural starch polymers, synthetic polymers or mixed with an additive from traditional polymers in order to degrade.

4. Product design: A branded T-shirt

Our traditional design strategy focuses on producing more, selling more and often even obsolescence is planned for a product in order to create space for brand new products, even though the initial product could be used for long. Circular design finds a way to manufacture products with optimal materials to deliver the highest value while minimizing the detrimental effects over the entire life cycle.[50] To make this possible, products and materials should be designed and chosen in such a way so that they can be easily disassembled, recycled or reused. A T-shirt is such a simple piece of clothing but designing this product for a circular economy is an inescapable step that is significantly important to ensure its reutilizing and recycling. Simultaneously, If a T-shirt is made of organic cotton or recycled material, it does not necessarily mean that this T-shirt is sustainable; the way it was designed and produced plays a significant role here.[51] Thus, proper designing can help to minimize the negative social and environmental effects during the value chain and in the end, less product will join the waste stream. The followings are some approaches to be applied in circular product designing.

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[48] Cf. Online: Milans (1988)
[49] Cf. Online: ExcelPlas; Centre for Design & Nolan (2003)
[50] Cf. Online: Aho (2016)
[51] Cf. Online: Sandin et al. (2019)

4.1. Design for longevity and circularity

A t-shirt intended to be circular must be designed with its material longevity and circularity in mind. Designing for longevity means to expand the active lifetime of a complete cloth, comfortability, durability, reparability, and enduring design which should be concentrated here.[52] Fibre composition significantly affects an item's life span and cyclability and in terms of durability, fibre's strength, abrasion resistance, odor, stains and tears which need to be considered here to work on the further design process.[53] Designing for circularity explores the opportunities to keep the product materials in utilization state, rather than letting the materials end in landfills after its use phase.[54] The first step would be pointing out each material of a product, like fibre, sewing thread, button, patch, dyes, additives, packaging materials and so on and then consider how each material can be processed for reuse or recycle. Thereby, it is essential to design a product that can be recycled easily.[55] Transparency also needs to be maintained to speed up the sorting process of the materials. In order to make a reasonable design decision, the time span of materials circularity needs to be considered as well.[56] At the same time, since mixed fibre recycling and biodegradability are still limited, the choices of material would have a huge impact on the ecosystem.

4.2. Choice of materials

Materials choice is usually prepared while developing the product to know what type of yarn, fabrics and other trims should be used. Since different fibres and other materials are made from different resources, that is why those will have different impacts on the environment and climate. Sustainable fibre manufacturing and making sure of choosing safe materials are the key concerns here in the choice of materials. Figure 3 below shows the comprehensive list of materials for a T-shirt model which should be considered while choosing the right materials.

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[52] Cf. Online: European commission (2019)
[53] Cf. Online: Design for longevity (n.d)
[54] Cf. Online: The Council of Fashion Designers of America (n.d)
[55] Cf. Online: Gulich (2006)
[56] Cf. Online: Mistra future fashion (n.d)

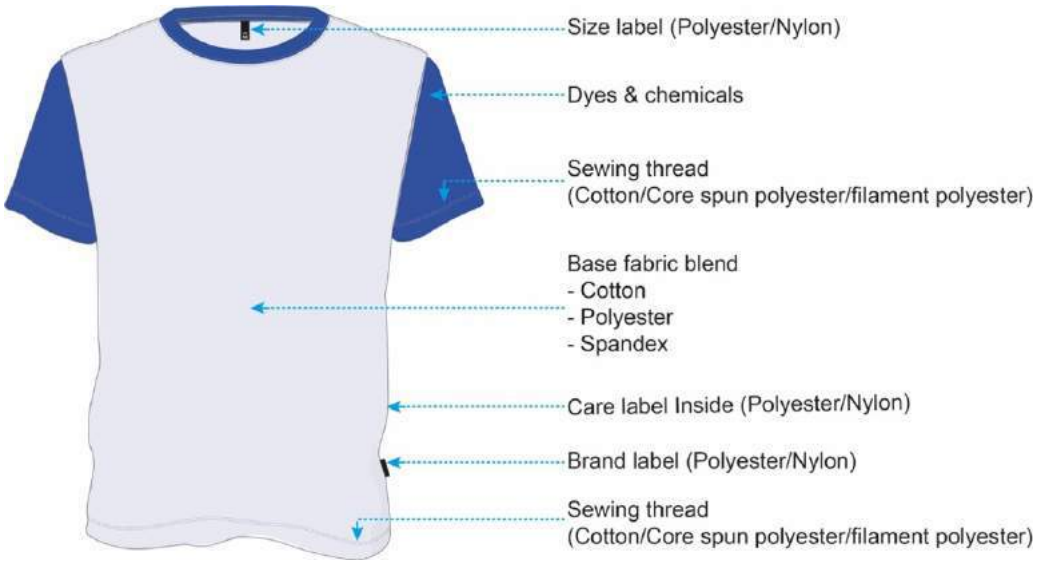

Figure 3: Materials in a T-shirt

(Source: Adapted from Ellen Macarthur Foundation, 2016)

The “Bill of Material (BOM)” is an important item in achieving industrialization and the manufacturing process in the circular economy-oriented clothing industry.[57] Below table 1 bill of material chart is developed based on industry experience on T-shirts with a focus on possible fibre materials for yarn and sewing thread.

T-shirt	Yarn	Sewing thread
Option 1	100% COTTON	Cotton
Option 2	100% Polyester	Core spun polyester
Option 3	100% Merino wool	Filament polyester
Option 4	100% Nylon	Filament nylon
Option 5	Cotton/Polyester blend, e.g. 80% COTTON, 15% POLYESTER, 5% spandex	
Option 6	80% COTTON, 20% VISCOSE	
Option 7	50% Polyester, 50% Nylon	
Option 8	95% cotton, 5% spandex	

Table 1: Bill of material for possible fibre types in T-shirts

(Source: Own analysis based on industry experience)

A specific bill of materials for a single T-shirt per gender can be found in Table 2. It takes into account all the materials like blends of cotton, polyester and spandex

[57] Cf. Online: Wearesustainn (n.d)

and the accessories that remain on the T-shirt, for example, sewing thread, care label, brand label, and so on.

Materials	Men T-shirts(g)	Women T-shirts(g)	Babies T-shirts(g)
Cotton	122,25	114,55	71,59
Polyester	25,30	23,71	0
Spandex	0,40	0,37	0
Care label	0,60	0,60	0,60
Brand label	0,25	0,25	0,25
Sewing thread	1,60	1,60	1
Total weight	150,4g	171,08g	73,44g

Table 2: Bill of material for a T-shirt model

(Source: Adapted from Product Environmental Footprint Category Rules, 2019)

A bill of material helps businesses with ways to track their development, analyze environmental and supply chain risks as well as make sure that their product materials' characteristics fit in a circular economy-based business model.[58] At the same time, physical and chemical characteristics of the material effectively leverage the transformation to circularity and these characteristics contain material composition, elements, appealing value, financial value, unhealthy and degree of impurity.[59]

Raw materials selection plays a fundamental role in designing a t-shirt for a circular economy. But using the aforementioned diversified raw materials in a single product can cause challenges to achieve principles like reduce, reuse and recycle which could shape the circular economy framework.[60]

5. Challenges and barriers

In the progress towards the circular economy, the clothing industry seems to be started progressing. But, even though, based on environmental and economic

[58] Cf. Online: Circular design guide (n.d)
[59] Cf. Online: Dieckmann et al. (2020)
[60] Cf. Online: Koszewska (2018)

literature review, expert interviews from online and inputs gathered from experience, a wide range of challenges and barriers could be recognized which restrain the transition towards a circular textile economy. These are further analyzed below.

5.1. Materials Purity

In general, purity in a material's level can only be expressed to be more or less pure than its original form. There is a significant escaping point in maintaining materials purity because of the complexity of fibres and the reproduction of them from different industries. Furthermore, the biggest potential challenges lie within technology to recycle and reuse materials with unchanged quality.[61] If the fibres like cotton or wool are recycled mechanically, which included shredding the fibres and reduce the material quality, there will be limited amount that can be reused in clothing at the end.[62]

5.1.1. Recycled Cotton

By far, cotton is the world's most well-known regular fibre where much of it is being used for the clothing industry. Therefore, it would be a great deal, if a cotton T-shirt can simply be recycled into new garments once its time is up. Regrettably, recycling an old garment is not that simple. To convert to a new garment from an old T-shirt, it needs to be chopped up. In general, ultimately, it degrades the quality of the fibre, which means, only a limited amount of fibre can be reused or recycled in clothing. Since the fibres get weaker during the mechanical process, the industry usually blends it with other fibres to turn it into a new or virgin fibre with the desired strength and resilience.[63] Consequently, further recycling is not possible from this blend. At the same time, not more than 30% of recycled cotton can be added to a clothing product.[64]

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[61] Ibid., 10.
[62] Cf. Online: Hare (n.d)
[63] Cf. Online: Grasso (1995)
[64] Cf. Online: Natureresearch (ed.), (n.d)

5.1.2. Managing mixed fibres

Blending fibres is a popular practice in the textile industry in favour of the specific applications. It is actually done because of additional wearing comfort as well as a good look for a long time. But the problem arises to reuse this mixed fibre due to its complexity. To figure out how to isolate mixed fibre materials so they can be reused separately by their own framework is one of the biggest challenges. For example, a T-shirt that is 95% cotton and 5% spandex cannot be recovered from landfills since it is difficult to separate spandex from cotton once they are attached to each other with heat. On the other hand, recycling cotton-polyester blend first comes with separating them, but 'mechanically' this is not an easy process and even if it is done to close the loop as per circular economy, it will only be treated as 'downcycling' because fibre will be shorter and weaker as it will lose its strength.[65] However, it can be achieved chemically by concentrating on its physical polymers' properties but there are drawbacks since this system is in limited capacity currently and that is why this lack of enough chemical recycling technologies leaves mechanical recycling as the only way for fibres to be reused.[66]

5.1.3. Fibre contamination

The fundamental function of contamination is to decide the quality of fibre especially cotton besides its other properties like fineness and strength. A single contamination can downgrade the yarn, fabric and even the final product, which may cause harm in the relationship among growers, spinners, buyers, retailers. Fibre contamination causes wastage of fabric due to dyeing defects, also even if the contamination is cleaned by processing the yarn, it may have an effect on product quality and value later on.[67] And having these issues, a product like T-shirt cannot be treated as a circular product.

5.1.4. Additives

Many different types of additives are being launched every year enhancing the material quality besides increasing materials complexity. For example, in the textile fibre manufacturing process, fibre needs to be spun into yarn, this process

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[65] Cf. Online: Östlund (2015)
[66] Cf. Online: Motte (2017)
[67] Cf. Online: Kumar (2015)

needs certain chemicals like spinning oil and without this, the outcome of the product will not be desirable. Hence, developing a pure material is also becoming difficult after many cycles, specifically if the product is collected from different sources and then it can contaminate others too. Moreover, bio-based fibres like biopolymer fibres are also not necessarily biodegradable just because they contain additives.[68]

5.2. Recycling limitations

Recycling provides the potential for a circular framework through closing the cycle between production and environmental components.[69] And recycling in textile is one of the oldest and most innovative sectors committed to the elimination of textile waste from the solid waste stream in order to put it back to market as a new product.[70] However, there are some limitations in recycling clothing which are described below.

5.2.1. Maintaining fibre quality

In terms of quality, a customer usually has the same expectation from a product with recycled fibre as the regular product. But in multiple processes of manufacturing and recycling, material quality cannot yet be maintained at its original state. The fibre bonding properties always get weaker every time they are recycled. As a matter of fact, the intrinsic nature of the recycling method creates short-length fibres, non-uniformity, unopened, or partially opened fibres and further imperfections.[71] As a result, fibre strength and elasticity decrease, sometimes it might also get pilling effects and this situation mostly happens to cotton; also, since the reproduction of fibre materials are increasing, it is actually getting difficult to contain them in reverse chains which leads it to lower quality respectively.[72] Eventually, these issues restrain the recycled fibre production, for example, the amount of collected textiles of high quality appropriate for recycling, has been gradually decreasing, about 65% of accumulated post-consumer textiles was

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[68] Ibid., 10.
[69] Cf. Online: Amini et al. (2007)
[70] Cf. Online: Hawley (2009)
[71] Cf. Online: Vadicherla & Saravanan (2017)
[72] Cf. Online: Ellen MacArthur Foundation (2014)

suitable for reuse about 20 years ago, but nowadays, this portion has now decreased to 50%.[73] Furthermore, since recycled fibres are often associated with lower virgin fibre content, consumers can often impede the molecular integrity of the fibres by general wash and wear.[74]

Textile recycling methods are categorized as mechanical, chemical and thermal recycling. Below table 3 attempts to accumulate the mentioned negative effects of these different recycling methods on the properties of the most commonly produced and used fibres that is cotton and polyester.

Fibre types	Effects of the fibre quality
Cotton	▪ Mechanical recycling: Length of the fibres reduces, which may limit the capacity for further recycling.
Polyester	▪ Thermal recycling: Weakens the quality of the fibre at the polymeric level. ▪ Chemical recycling: Quality of the end product is equal to fibres from virgin polymer. But it is still unknown that how many times it can be recycled further or if it is limited to single process. Also, it is more expensive process than the thermal recycling.

Table 3: Effects of recycling on fibre quality
(Source: Adapted from Heikkilä et al.-2019)

The Blended fibre material is another challenge to deal with while approaching to fibre-to fibre recycling. As already stated earlier that blended fibre is generally practiced accomplishing specific application, this however makes them difficult to purify in the sorting and separation process afterward.[75]

5.2.2. Lack of technical skills

Currently, it is actually less expensive and easier for companies to utilize the existing technology that they are already using and to take help from their

[73] Ibid., 1.
[74] Cf. Online: Palme et al. (2014)
[75] Ibid., 18.

suppliers in order to get technical support. That is why, those companies lack the technical capacity to perform well to implement and further develop the more specialized technical choices, which could have helped them to reduce the ecological footprint, save costs and consequently proceed towards circular fibre initiatives.[76] On the other hand, currently, there is not enough infrastructure or technology for large scale recycling processes of textile fibres.[77]

5.2.3. Removing colours and persistent chemicals

Within the area of fibre and textile waste recycling, colours present big issues. There are some choices for controlling colour in textile waste such as, collecting and sorting cotton waste based on its colour to eliminate the colour[78] or mix the waste textiles, generate staple fibres with brownish shades,[79] after the manufacturing process, the blend may likely be bleached afterward to eliminate colour.[80] What happens here, is that the process actually breaks down the dye molecules that can no longer reflect the light creating the appearance of “no colour”, but the molecules are still there even though it is not apparent; these molecules could create some impurity to the fibre and make it difficult to recycle further and would still interfere with further processes.[81]

5.2.4. Difficulties in sorting and separation

The most critical step toward a circular economy, perhaps, is to transform obsolete goods back into new ones. Fibres can be recycled manually or chemically, but at the same time, it is also important to fix barriers to sorting and separating ever-growing used cloths and waste. Numerous clothing products are a combination of various fibre materials in today’s fashion practice. To get pure materials and to find the proper way of segregating blended fibre materials to recycle and reuse them based on their own properties is a challenge. Reviewing the industry, it could be assumed that a few numbers of product properties fit more efficiently into the circular economy than other industries. A 100% organic cotton solid T-shirt without

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[76] Cf. Online: Trianni & Cango (2012)
[77] Cf. Online: Recovery-worldwide (2019)
[78] Cf. Online: Esteve-Turrillas & Guardia (2016)
[79] Cf. Online: Heikkilä (2018)
[80] Cf. Online: Määttänen (2019)
[81] Cf. Online: Schuch (2016)

any extra attachments to it like a pocket, button, zipper, placement print and patch label would be much easier than a T-shirt with much complex integrated components. Sometimes, there is no cost-efficient way to separate the embedded raw materials using a physical or chemical process without hampering the product quality.[82]

In the circular economy model, at the beginning of the life cycle of products, designers usually assign various raw materials keeping their circularity process in mind. And based on that, they prepare a sequencing model to disassemble them at the end of the product's life cycle; but this sequencing model could be unrealistic or complex to other actors who are actually going to separate the product materials.[83] Sometimes, many complications may arise in the separation process, for example, while hazardous parts are allowed to disassemble, it affects the environment negatively rather than being a secure process that was initially aimed to achieve the original quality and dispose of safely.[84]

5.2.5. Issues in plastic recycling

To begin with, there are several kinds of plastic which make it difficult to sort properly, for example, when we throw the plastic bags in the particular bin it generally turns out to be a combination of recyclable and non-recyclable plastic bags, that unfortunately have to be separated again which might not be performed again by all other concerned parties. These ultimately will disturb the recycling steps for its next life cycle.

The available post-consumer collection schemes and material recovery facilities are usually for rigid plastic packaging since flexible packaging has various properties and appears to be troublesome during the collection and sorting processes.[85] In addition, because of having a low weight-to-volume ratio, it is not economically feasible to invest in the necessary facilities.[86] Keeping plastic in a cycle to use endlessly is not practical, it will inevitably end up in a landfill. There

[82] Cf. Online: World economic forum (2014)
[83] Cf. Online: Gupta & Veerakamolmal (1996)
[84] Ibid.
[85] Cf. Online: Hopewell, Dvorak, & Kosior (2009)
[86] Ibid.

are limits on how many times plastic recycling can be done. Plastic has fibres and since we already know fibre shortens and weakens every time it is recycled, that means it can no longer be used after a certain number of recycling.[87] It is usually possible to recycle plastic 7 to 9 times until it is not recyclable anymore.[88]

5.3. Environmental and sustainability issues

The Circular economy is one among foremost recent methods of addressing environmental and sustainability concerns.[89] Circular economy and sustainability are interlaced firmly, where it is tough to imagine a state whence sustainability can be accomplished without the circular economy. While implementing the circular framework, it is crucial to provide a particular focus on avoiding waste and preserving the value of materials. Sustainable clothing brands with a circular economy-based business model face a paradox since they promote messages of couscous consumption to change the consumption patterns of customers while trying to sell more products.[90]

5.3.1. Impacts of bringing raw materials in

In 2018, global fibre production was around 107 million metric tonnes and it is expected to reach around 145 million metric tonnes in 2030 if business continues as usual. Also, the growth of cotton production and the creation of polyester combinedly has a market share of more than 80% of the global textile market, where cotton accounts for 26.05 million metric tonnes and polyester for 55.1 million metric tonnes.[91] Below figure 4 illustrates the global market share of fibres production.

[87] Cf. Online: National Geographic (2018)
[88] Cf. Online: Auckland Council (2016)
[89] Cf. Online: Murray, Skene, & Haynes (2015)
[90] Cf. Online: Han et al. (2017)
[91] Cf. Online: Textile exchange (2019)

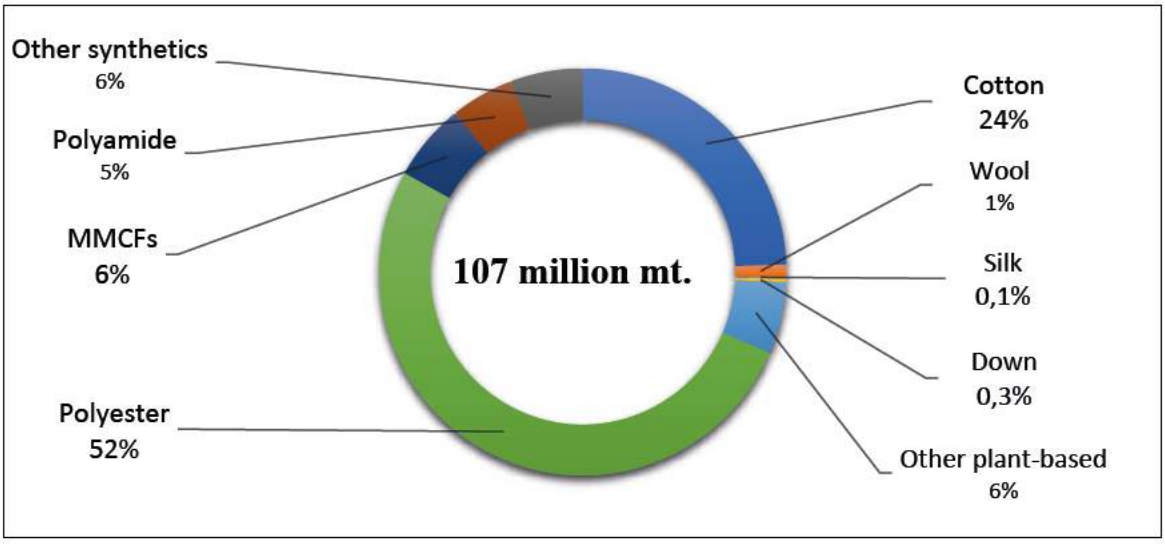

Figure 4: Global fibre production in 2018
(Source: Adapted from Textile exchange, 2019)

But the industry is dominated by cotton, which accounts for more than 43%, followed by polyester in terms of the clothing manufacturing weight; acrylic, wool and viscose each makeup about 10% of the industry.[92] Figure 5 below shows the percentage breakdown of consumption by fibre form for the clothing industry.

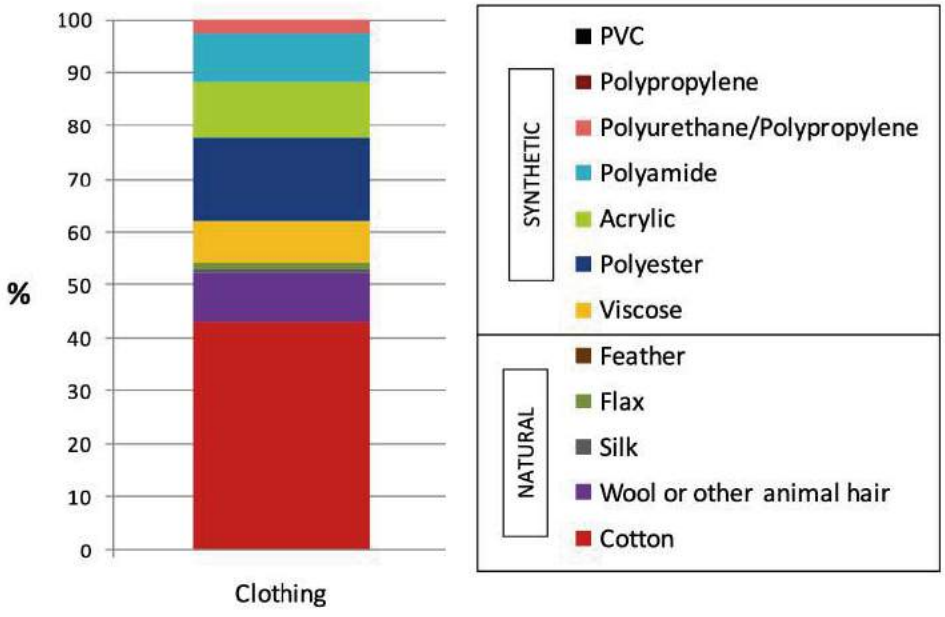

Figure 5: Percentage breakdown of clothing consumption by fibre type
(Source: Adapted from European Commission, 2014)

[92] Cf. Online: European Commission (2014)

Cotton is a cellulose fibre, a natural, biodegradable and renewable resource; that is why it is supposed to be an environmentally friendly fibre.[93] In contrast, growing cotton conventionally is literally one of the significant challenges to the environment because of its necessity for a notable amount of chemicals to account for its sensitivity to insects and fungi.[94] To grow typical conventional cotton, it takes a comprehensive number of pesticides. Furthermore, it is also recognized that the clothing industry discharges high volumes of hazardous chemicals with water into the environment. For instance, dyeing and treatment plants in this industry are accountable for around 20% of industrial water pollution globally.[95] Considering a purchase of a 250g cotton T-shirt will imply purchasing 1.7kg of fossil fuel, depositing 0.45kg of waste to landfill and releasing 4kg of carbon dioxide (CO_2).[96] The production of plastic is another source of carbon emission within the environment. Overall, this industry is one of the reasons behind carbon dioxide (CO_2) emissions which are causing adverse impacts on the environment as shown in figure 6 below.

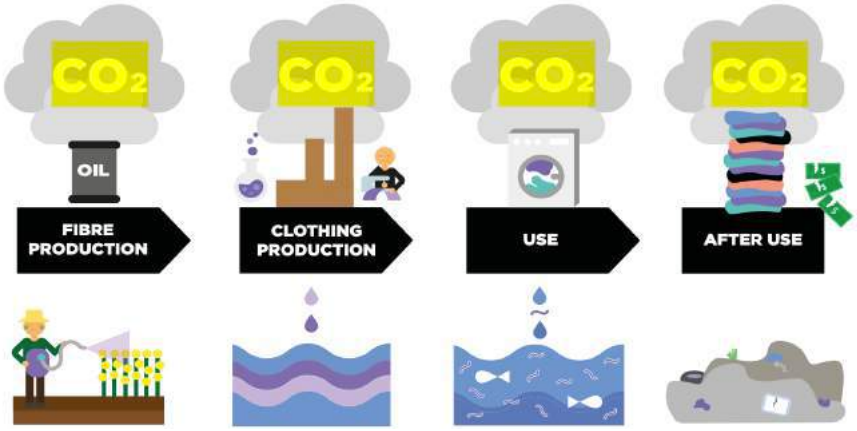

Figure 6: Environmental consequences of today's clothing industry
(Source: Ellen Macarthur Foundation, 2017)

Nonetheless, consequential use of chemicals is not the only drawback of conventional cotton, growing textile fibre also has a significant impact on regional water bodies. The clothing industry including cotton farming consumes annually 93

[93] Cf. Online: Clay (2004)
[94] Cf. Online: Chen & Burns (2006)
[95] Cf. Kant (2012)
[96] Cf. Online: Well dressed (2006)

billion cubic meters of water, sufficient to meet the requirement of 5 million people worldwide.[97] In terms of water-scarce areas, many leading cotton-producing countries are under water scarcity which includes China, India, and US. Around 90% of the fabric, yarn and synthetic fibres are produced in water-scarce regions in China.[98] Also, by 2025, it is forecasted that 1.8 billion people might encounter water shortage.[99] A simple cotton T-shirt requires water what might be compared to the three years of drinking water of 2,700 litres to manufacture and use and this is basically enough for one person to drink for 900 days.[100] Figure 7 below illustrates the volume of water consumption for one cotton and polyester-based T-shirt.

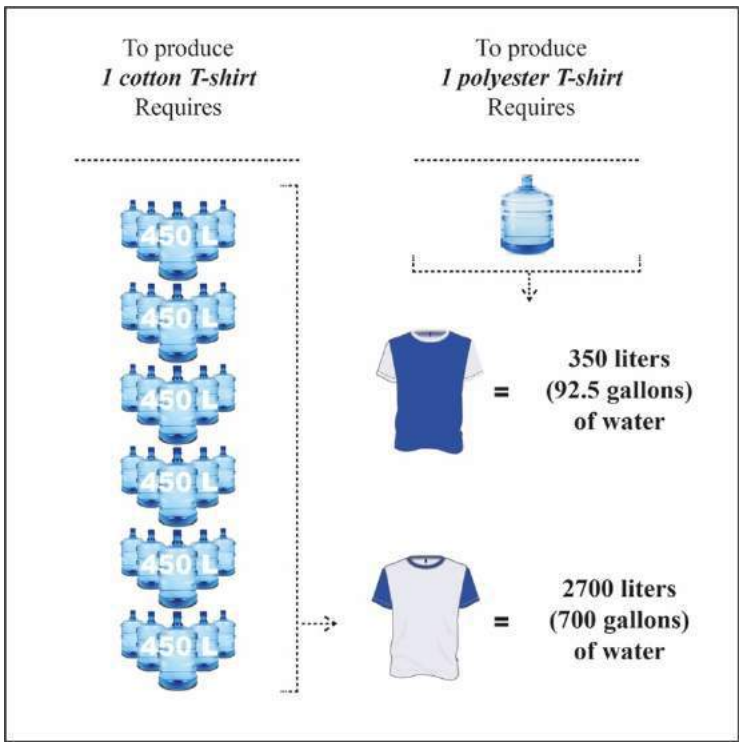

Figure 7: T-shirt's water footprint
(Source: Adapted from Leahy, 2014)

Considering the aforementioned value, the global average virtual water content can be decided too. Of this total water volume, 46% is blue irrigation water used by cotton plants. 41% is green rainwater and 14% is grey water used in the

[97] Cf. Online: United Nations Conference On Trade And Development-UNCTAD (2020)
[98] Cf. Online: Maxwell, McAndrew, & Ryan, (2015)
[99] Cf. Online: UN-Water & FAO (2007)
[100] Cf. Online: WWF (2013)

operations and washing. The virtual water content of a few more specific products is shown in Table 4.

Product	Standard Weight (g)	Virtual water content (litres)			
		Blue water	Green water	Dilution water	Total volume of water (litres)
1 pair of Jeans	1000	4900	4450	1500	10850
1 bed sheets	900	4400	4000	1350	9750
1 Diaper	75	370	330	110	810

Table 4: Global average virtual water content of selected products
(Source: Adapted from Chapagain et al., 2005)

Compared with cotton, a synthetic fibre like polyester is also popular having a reputation to be the “workhorse fibre of the industry”.[101] Even though polyester takes less water and land to be produced, it consumes non-renewable resources which emit into the air and water causing damage to the environment if it is not treated before.[102]

5.3.2. Global waste generation and impacts

It has become a global unity to develop a circular economy by promoting sustainable development. And the complete use of textile and clothing waste should add contribution to sustainable development. But the natural outcome of the present clothing production and consumption model is increasing the demand for fibres and expanding waste.[103] Here, waste is in every stair of the value chain of a product which is hardly being used efficiently these days. Furthermore, fast fashion is inspiring consumption and waste generation.[104] It has been also commonly stated that there are ‘fast-fashion’ products of extra low quality entering the clothing waste stream which hold much less value. The European textile industry produces waste of approximately 16 million tonnes per year.[105] Annually,

[101] Ibid., 15.
[102] Cf. Online: Fletcher (2008)
[103] Cf. Online: Smits, Cunningham, & Spath (n.d)
[104] Cf. Online: Environmental Audit (2019)
[105] Cf. Online: European commission (2017)

around 92 million tonnes of textile waste is being created from the clothing industry and it is forecasted that it could increase by approximately 60% by 2030.[106]
A significant portion of waste generated from the clothing industry is polybags from plastic film. Now, there are some reasons the industry is settling with this option instead of using other alternatives. Apart from being energy efficient while manufacturing and lighter than other alternatives, polybags protect the garment from dirt, damage, assist in promotion to make more marketable[107] and most importantly prevent moisture while transporting them from manufacturing units to end consumers. Because of these desirable physical properties and for low manufacturing cost, the use of these plastic polybags is increasing thus causing more waste. Since 1950, plastic manufacturing has increased by an average of 8.5% each year and as shown in below figure 8, around 350 million metric tonnes are manufactured globally.[108]

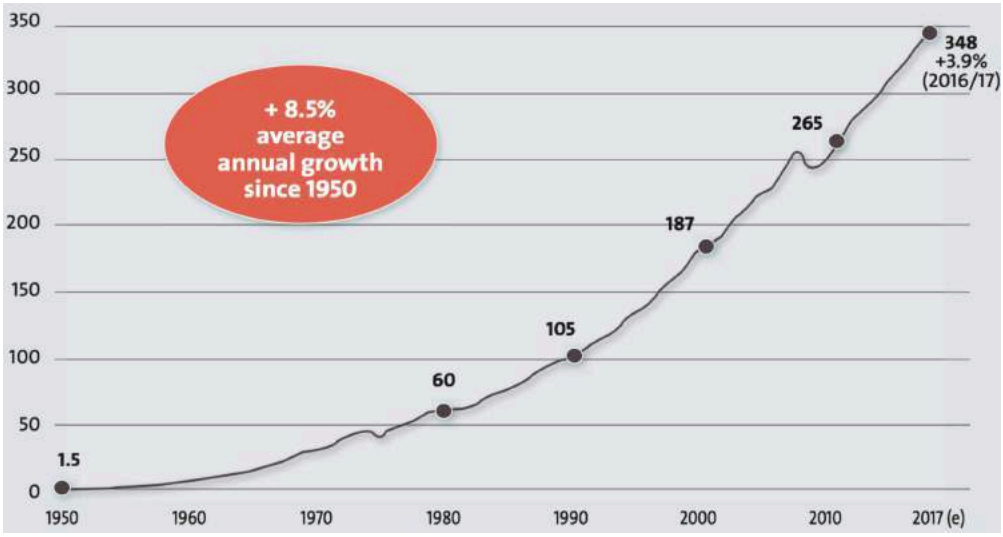

Figure 8: Global plastic production (million metric tonnes)
(Source: Chalmin, 2019, adapted from PlasticsEurope Market Research Group)

Generally, the use of polybags starts in garment manufacturing units where the garment suppliers pack the garment with polybags. Now, the number of polybags they use is another factor. For example, if a brand order for 50,000 pieces of T-shirt to a supplier, that supplier will order 2% to 5% (based on their worker

[106] Cf. Online: Lehmann et al. (2019)
[107] Cf. Online: Entrepreneur (n.d)
[108] Cf. Online: Chalmin (2019)

efficiency) more polybags as wastage percentage to avoid last-minute shortage of polybags; after shipping that order, the re-use of leftover polybags is uncertain. On the other hand, from an e-commerce perspective, there could be 30% to 50% of returns of product from customer back to retailer.[109] When the product is received, it gets unpacked, rechecked and then sent back to the customer in a new polybag where the old one is usually discarded. These packing operations generate a significant waste stream at both manufacturing and distribution centres.[110] An additional noteworthy issue is that currently, North America and Europe are leaning towards transferring the use of plastic polymers and plastic manufacturing to Asia, where most of the countries do not possess efficient recycling and waste management scheme.[111]

The discarded plastic bags, bottles, toys, and so on are not the only causes of the pollution just because they are visible. There are hair-like plastic fibres also coursing through our environment, called ‘microplastic’ or ‘microfibre’. Besides other waste problems, this is another significant issue coexisting in the clothing waste problem, which is happening frequently due to domestic laundry of synthetic fibre made clothing.[112] Apart from the domestic use phases, textile manufacturing and processing or recycling are another noteworthy sources of microplastic. These microscopic fibres originate mainly from clothing made of synthetic fabrics, for example, polyester, nylon, and so on. They can enter the human food chain and cause threats to human health through inhaling or consuming food.[113] Furthermore, there are chemical impacts of microfibres on the environment which includes leaching harmful chemicals, for example, dyes and antioxidants.[114] Figure 9 below indicates that microfibre release can occur at several stages in the textile supply chain and thus can affect human health and impact the environment through marine, freshwater and terrestrial habitats.[115]

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[109] Ibid., 10.
[110] Ibid., 10.
[111] Cf. Online: The National Academies Press (2020)
[112] Cf. Online: Henry, Laitala, & Klepp (2019)
[113] Cf. Online: Waring, Harris, & Mitchell (2018)
[114] Ibid.
[115] Ibid., 27.

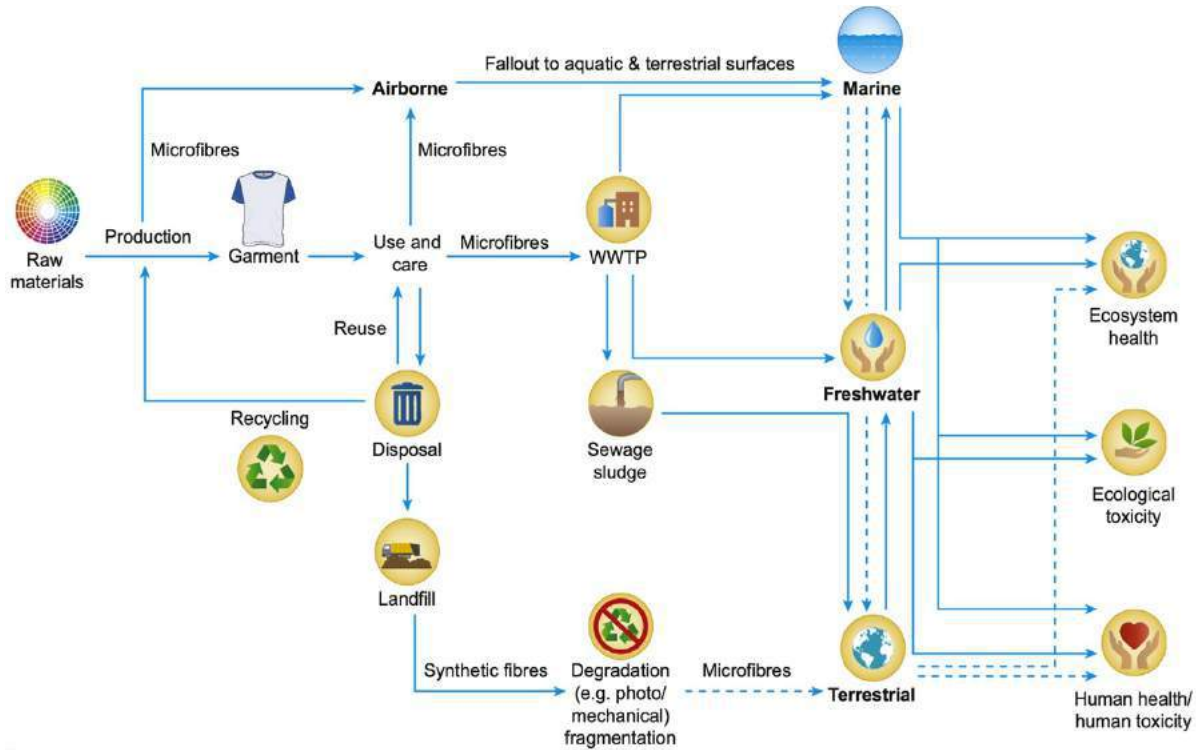

Figure 9: Potential pathways of microfibres to the environments causing impacts (Source: Adapted Henry, Laitala & Klepp, 2019)

These environmental challenges also pose threats to economic misfortunes. The larger part of these depends on how these wastes are treated. In a circular economy, it is necessary to recycle materials from waste to close the loop but nonetheless, any type of recycling, whether it is mechanical, or chemicals recycling to process fibre and turn them into new yarns, consumes energy, thus it actually means that it is only a way of managing waste, not a way of reducing it.[116]

5.3.3. Impacts of reuse and recycling

Worldwide demand for clothing is developing exponentially; at the same time, the industry is confronting immense natural and resource problems. Because of the challenges, there are regulatory concerns in growing textile reuse and recycling, which will drive the handling of textile waste back into the waste management systems.[117] Figure 10 outlines the classification of common ways of reuse and recycling in the clothing industry.

[116] Cf. Online: Aakko & Koskennurmi-Sivonen (2013)
[117] Cf. Online: European commission (2008)

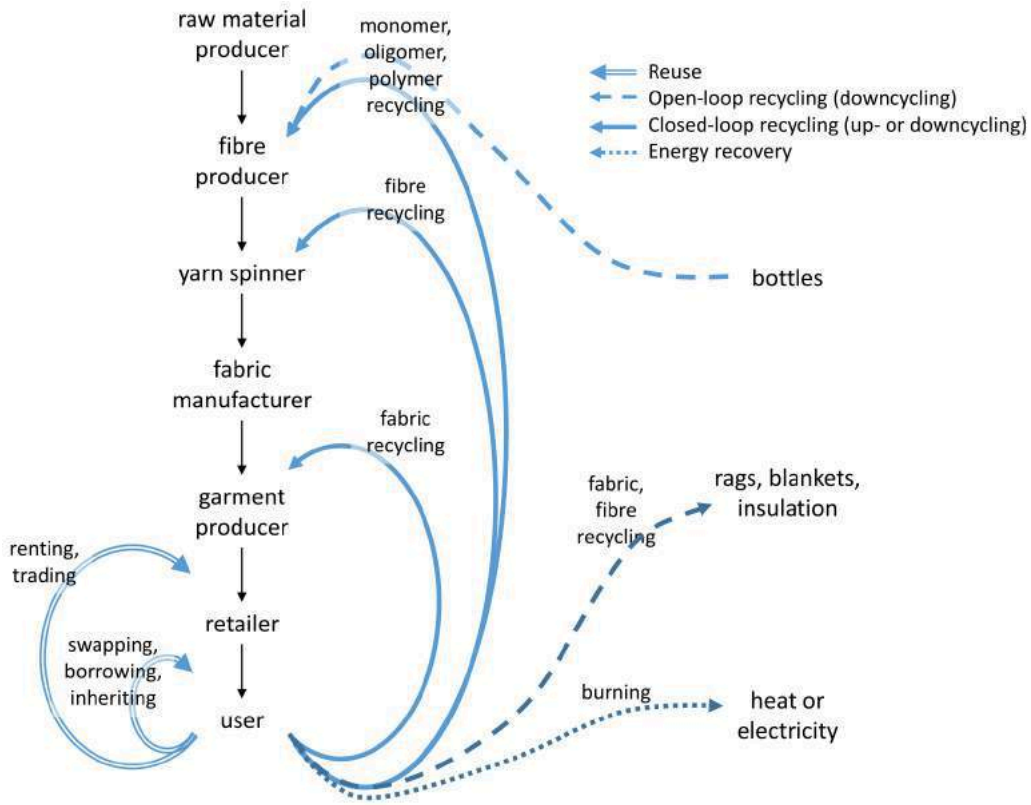

Figure 10: Outlines of various forms of reuse and recycling in clothing industry
(Source: Adapted from Sandin & Peters, 2018)

Increased clothing product reuse and recycling might decrease the manufacturing of virgin fibres and, within the case of reuse, also discourage further engineering processes in the product life cycle, which in turn possibly decrease environmental impacts. These increasing interests in reuse and recycling are also associate with the increased consideration given to the idea of circular economy.[118] While the positive effects of recycling and reusing from the clothing industry are apparent, there are few negative effects where their benefits have yet to be established;[119] some of the negative impacts are enlisted below.

- It is not known how much of reusing and recycling of cloths ultimately compensates for virgin material development and production; likewise, there are also uncertainties as to whether recycled fibres will replace virgin fibres since chemical recycling methods are still being developed.[120]

[118] Cf. Online: Sandin & Peters (2018)
[119] Cf. Online: Fortuna & Diyamandoglu (2017)
[120] Cf. Online: Dahlbo et al. (2017)

- One of the common concerns is that recycling sites are usually unhealthy because of vast volumes of textile waste discarded there with hazardous chemicals which can contribute to the toxication of water sources.

- The preparation process for textile reuse and recycling still requires energy; energies like mineral and electricity; for example, washing and drying of textiles after collection would lead to energy consumption of approximately 0.65 kWh, with a rise in primary energy consumption of approximately 5 MJ/Kg.[121]

- One of the key detrimental consequences of recycling is that the recycled product does not necessarily have a very long-lasting life and does not always pose high quality that eventually will lead this product to landfill.

- Different used products might have different hazardous chemicals in it and these substances could affect living organisms while recycling the products; for example, sportswear, workwear or other dyed cloths may contain 'biocides' (for odour prevention and hygiene applications), 'phthalates' (used to make plastics more flexible and harder to break), SCCPs (short-chained chlorinated paraffins) and colourants or pigments with toxic properties.[122] But the probability of the transition of dangerous substances to a finished recycled product is low here.[123]

- Recycling plastic packaging often poses potential threats to the environment. The method of dissolving down plastic makes a chemical called, VOC (volatile organic compounds) which can impact human health, plant and animal life close to industrial places. Moreover, the heat required to dissolve these plastics also causes carbon emission contributing to Global warming.[124]

- The textile industry also facing high added cost to clean, regenerate and source recycle product materials that may not always suit the circular

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[121] Cf. Online: Schmidt et al. (2016)
[122] Cf. Online: Östlund et al. (2015) & Ibid.
[123] Ibid.
[124] Cf. Online: Hartman (2017)

design ideas. On the contrary for many African nations, the huge trade in second-hand garment for recycling had negative socio-economic implications. Eastern African countries, for instance, Tanzania, Rwanda, and Uganda have imposed a ban on second-hand garments import to reinforce their own industries, which had suffered a significant blow because of recycling imported garments.[125]

5.3.4. Issues with chemicals from the products life cycle

When we go to the store to get our favourite colours' t-shirt with some cool prints on it, we usually check the label for price and sometimes see the fibre composition and wash instruction, what it does not say is that the t-shirt we are so excited about went through lot of chemical substances. In the clothing manufacturing process, the total weight of the chemicals used is more than the weight of the finished cloths; It has been estimated that between 1.5 to 6.9 kg of chemicals are needed to produce 1 kg of cloths.[126] At the same time, 1 kg of cotton T-shirts desires almost 3 kg of chemical compounds.[127] The whole textile sector is a dreadful user of chemicals for both fibre preparation and product manufacturing process and one of the lengthy and most diverse industrial chains in the manufacturing industry.[128]

In the beginning, cloths used to be coloured with natural dyes, but it has a low colours range and poor fastness; synthetic or chemical dyes, on the other hand, have good colours range and good fastness.[129] In textile manufacturing, the use of dyes, both natural and synthetic, is an important source of chemicals and has great impact on the environment.[130] Tonnes of chemicals are emitted from the textile industry into the water every year.[131] Most notably, this wastewater contains a significant number of pollutants that harm our environments, such as colour, pesticides and heavy metals.[132]

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[125] Cf. Online: Textile Consult (n.d)
[126] Cf. Online: Olsson et al. (2009)
[127] Cf. Online: Swedish Chemicals Agency-KEMI (2014)
[128] Cf. Online: United Nations Environment Programme-UNEP (2011)
[129] Cf. Online: Khatri & White (2015)
[130] Cf. Online: Kant (2012)
[131] Cf. Online: The World Bank (2019)
[132] Cf. Online: Richards (2015)

The adverse environmental impact of dyes exists not only on the fabric dyeing, but natural fibres can too damage soil and water when disposed of due to the chemicals used in their finishing processes.[133] The dyeing process of fibre releases chemicals that can still contain colours which are base of metal pollutants such as chromium and copper; if this is untreated, it can be detrimental to waterborne lives affecting the human food chain.[134] Man-made fibres like polyester and acrylic uses “Terephthalic acid” and ‘Acrylonitrile’ chemicals respectively in their manufacturing process that elevates ‘carcinogenesis’, the formation of cancer.[135] Additionally, the chemicals used in clothing also affect the health of everyone involved in both manufacturing activities and consumption.[136] A synthetic plastic polymer called polyvinyl chloride (PVC) used in t-shirt printing consist of softeners such as phthalates that can interfere with the human reproductive system.[137] Below table 5 attempts to provide a brief scenario of more various chemicals used in the life cycle of a T-shirt and probable adverse consequences interrelated with the chemicals in several life cycle stages.

Life cycle stages	**Chemicals**	**Impact indicators**
Fibre production	Pesticides - Atrazine, mirex, Malathion, Aldicarb	Ecotoxicity Eutrophication Human toxicity
	Fertilisers - Synthetic Nitrogen, Phosphorus	
	Crude oil - Petroleum	
Yarn production ▪ Spinning ▪ Knitting	Spinning oils, Lubricants, Needle oils	Ecotoxicity Eutrophication

[133] Cf. Online: Payne (2015)
[134] Cf. Online: The open university (n.d)
[135] Cf. Online: Singh & Bhalla (2017)
[136] Ibid., 4.
[137] Cf. Online: Manshoven et al. (2019)

Wet Processing ▪ Scouring ▪ Bleaching ▪ Dyeing	Detergents - Nonylphenol Ethoxylates, Octylphenol Ethoxylates	Acidification Ecotoxicity Eutrophication Human toxicity Salinisation
	Lubricants	
	Stabilizers - Sodium Silicate	
	Bleach - Sodium hydroxide-NaOH, hydrogen peroxide-H2O2	
	Dyestuff - Azoic, Reactive, Direct, Vat and Sulphur dyes	
	Salts - Aluminium, Chromium, Copper, Iodine, Potassium, Sodium, Tungsten, Potash Alum and Tin)	
	Softeners - Alkyl Phenol Ethoxylates	
	Finishing agents - Formaldehyde-based finishing agents	
Finishing ▪ Drying ▪ Printing	Air emissions	Ecotoxicity Human toxicity
	Prints - Formaldehyde-based pigments in discharge printing	
	Finishing agents - Formaldehyde-based finishing agents	
Sewing	Stain removal - Carbon tetrachloride	Ecotoxicity Human toxicity
Distribution and retail	Container gas, Fuel combustion	Acidification

Use phase	Biocides - Formaldehyde (bactericide) and permethrin (insecticide)	Human toxicity
Maintenance phase ▪ Laundering	Detergents - Formaldehyde, Parabens, Phthalates, Triclosan	Ecotoxicity Eutrophication Human toxicity
	Softeners - Phthalates	
Waste Management	Pollutants in recycled materials	Ecotoxicity Human toxicity
	Chemicals in water and air emissions	
Ecotoxicity – Refers to the toxic effects of chemicals on the ecosystem, for example, chemicals that get into the environment can lead to biodiversity loss.		
Eutrophication – Heavily dyed textile wastewater seriously impacts the photosynthetic role of eutrophication in plant and aquatic life.		
Human toxicity – Indicates the effects on human health caused by direct exposure to toxic chemicals.		
Salinisation – Soil fertility can severely be diminished due to increased collection of dissolved salts of sodium, magnesium and calcium.		
Acidification –Carbon dioxide from the combustion of gas and fuels can enter ocean water making it more acidic.		

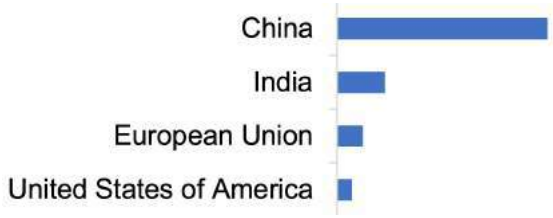
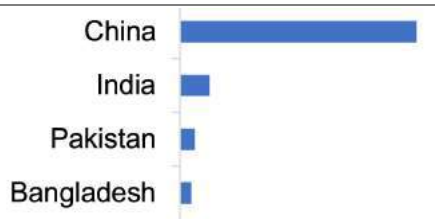
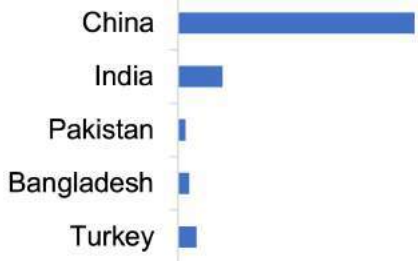
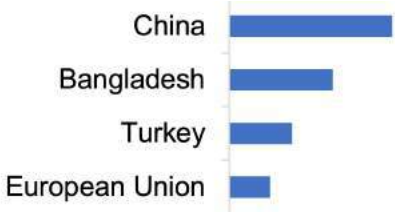
Table 5: Chemicals used in a T-shirt and probable adverse effects associated with the chemicals

(Source: Adapted from Roos, 2015; Newman, 2010; Mani, 2019; McKone & Hertwich, 2001; EUROPEAN SOIL DATA CENTRE-ESDAC, n.d; Natural Resources Defense Council (NRDC), 2009; Textile Guide, Chemsec, n.d.; Environmental Justice Foundation together with Pesticide Action Network UK, 2007; Kooistra et al., 2006; GTZ, 2009; The Good Shopping Guide, n.d.; Kabir et al., 2019; Brahma et al., 2019; Gulzar et al., 2019; Acero et al., 2015; Krewitt et al., 2002; solverchem, n.d; Jain, 2017)

5.4. The trend of global sourcing

The globalisation of clothing sourcing in the fashion industry with different and scattered manufacturers for a variety of global brands is already established. Furthermore, the geographical distribution of the clothing business has been facing a noticeable shift from developed to less developed or developing

countries.[138] This method of production organization has been captured through the study of the global value chains (GVC) system where the brands possess high valued activities for example design, distribution, marketing and retailing at the same time, sourcing low-cost activities from manufacturers in developing countries.[139] From raw material extraction to finished product manufacturing, most of the value chain is heavily weighted towards countries like China, India, and Bangladesh in Asia and other developing economies[140] as shown in table 6 below.

Life cycle stages	Operations	Global Share
Fibre production	Raw material production Material processing and sourcing Fibre reparation	
Yarn and fabric production	Spinning	
	Weaving or knitting	
Clothing production	Dyeing and finishing	

[138] Cf. Online: MacCarthy & Jayarathne (2010)
[139] Cf. Online: Gereffi (1999)
[140] Cf. Online: United Nations Environment Programme-UNEP (2020)

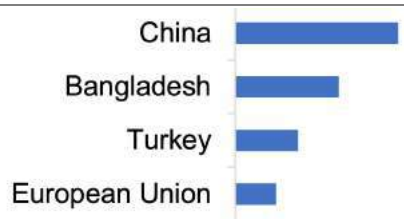
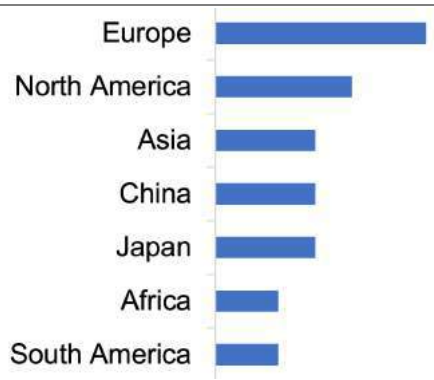
	Assembly	
Consumption	Distribution and retail	
	Use phase	

Table 6: Global clothing share of production and estimated share of consumption (Source: Share of production adapted from Quantis, 2018 and estimated consumption from United Nations Environment Programme-UNEP, 2020)

This global sourcing tendency of this industry is assigned to one of the two types of the brands; one with their own production facilities, such as clothing brand Benetton, another one is with no own manufacturing facilities, such as C&A, H&M, Primark, and so forth.[141] For instance, as per the supplier list published on C&A official website, they have only 4 factories in Germany, on the other hand, they source the major portion of their products from countries like China with 244 factories, Bangladesh with 146 countries, Turkey with 118 and India with 75 factories.[142]

In terms of sourcing new materials, materials could either be durable, recyclable or biodegradable depending on the design approach. But these sourcing practices might cause extra cost. Furthermore, because of the lack of support from supply networks, many suppliers are disagreeing on the initiatives of the green supply chain, which consequently leads to high costs and loss of competitiveness.[143] For example, when C&A started their C2C 100% organic cotton-based T-shirt in a circular paradigm, it took around 8 months to source suitable dyes, at the same

[141] Cf. Online: Crestanello & Tattara (2009)
[142] Cf. Online: C&A (2018)
[143] Cf. Online: Eltayeb & Zailani (2009)

time, the Indian supplier who was producing this T-shirt, had to import organic sewing thread from Switzerland which is ten times the price of traditional sewing thread, causing the final retail price of the T-shirt higher than C&A's typical T-shirt price.[144]

In global value chains, clothing products are consumed a long way from the places where they have actually been manufactured which is again a linear motive.[145] This linear production and consumption model is hugely wasteful of resources and has led to unfortunate consequences on the environment because of energy consumption from transport and additional carbon dioxide (CO2) emissions, as most of the products are traveling by ship. At the same time, the fast fashion has really influenced the lead time issue which leads to quick transport by truck or even by air resulting in a higher carbon footprint.[146] At the same time, it is also commonly cited that more low quality, 'fast-fashion' products entering the clothing market making it more difficult to preserve the product based on waste hierarchy.

5.5. Complications in supply chain

Before a customer buys a new t-shirt, it has already traveled a great distance on trucks, ships and airplanes and a lot of hands worked for it. Across the globe, various players are linked together like suppliers, vendors, logistics, and retailers. To encourage a more effective supply chain, it is important to realize which steps are included. In a circular economy, products are observed over their complete life cycle and every step of the supply chain is included in it. Accordingly, if companies decide to restructure their supply chain for the circular economy, may secure social, environmental and economic advantage.[147] In a linear economy, the supply chain focuses on manufacturing and distribution of mainly non-durable goods and hardly pursues the closing loops concept.[148] The most significant challenges in transforming towards the circular economy are the merging with recyclers who supply high-quality material on the one hand and the producers who buy these

[144] Cf. Online: Makower (2017)
[145] Cf. Online: United Nations Industrial Development Organization-UNIDO (2020)
[146] Cf. Online: Saicheu, Knox, & Cooper (2012)
[147] Cf. Online: Cucchiella et al. (2015)
[148] Cf. Online: Fennemann et al. (2018)

materials and offer restoration service on the other hand.[149] Nowadays, chemical contents of product are often managed by the remote supply chain players where the brands do not have that much access.[150] Furthermore, due to complex, long, and global textile chains, it is also tough to keep track of all the hazardous chemicals that are being used in the products.[151] Additionally, there are issues in cooperation and transparency where suppliers and manufacturers merge. It is difficult to achieve, bringing an effective supply chain into existence with partners who do not want to work alongside and be really transparent about their supply chain.[152]

Reliability of supply is a significant prerequisite for many industrial applications for circularity. But the volume and blend of materials in today's assortment plans are variable, which in turn does not make them financially feasible.[153] It seems to be having some limitations also to find substitutes for fibres what textile industry uses the most, for example, cotton and synthetic fibres. On the other hand, there has been an active and growing discussion over the past years about the overarching new standards, multiplied supply complexity and the increased efforts necessary in the environmental management of textile chemistry.

Due to globalization, there are improved mobility and transportation systems. Therefore, circular economy noticeably increases the transport activities and especially the costs while sending the products to specialized sites for recycling or reusing in a closed-loop cycle. Krikke (2011) mentioned a case of implementing this cycle in a printing company's supply chain, the amount of transportation got tripled over ten years after implementing it.[154] Moreover, clothing companies demand that there is a limited supply of recycled fibres; on the other hand, recycled fibres suppliers report that there is a lack of demand from clothing retailers and manufacturers.[155] It seems like there still remains a substantial gap between supply chain collaboration exercises with a lack of interest from all

[149] Cf. Online: Wilts & Berg (2017)
[150] Ibid., 9.
[151] Cf. Online: Swedish Chemicals Agency-KEMI (2013)
[152] Cf. Online: Dutch Awareness (n.d)
[153] Ibid., 19.
[154] Cf. Online: Krikke (2011)
[155] Cf. Online: Elander & Ljungkvist (2016)

involved stakeholders. These actually result in difficulties of recycled products to market which consequently will lead to high prices.

5.6. Financial barriers

A lack of capital is often mentioned as a barrier to shifting towards a circular economy in various literature. In general, any investment in innovations is regarded to be complicated and risky since the aftermaths are uncertain. The investment cost for transforming an infrastructure is usually called a high upfront cost; while executing a circular economy the cost does not stream back because they are put in the cycle.[156] Tracking the resource flows and reforming the life-cycle of a product is expensive, at the same time some companies treat production services as a threat to their own business.[157] At the same time, firms tend to invest little in greenhouse gas emissions since the investment is costly and does not necessarily lead to profit in terms of output.[158] Furthermore, financing green innovations and the lack of access to investment funds are significant barriers especially for start-ups where labour and operations costs, repairs and logistics are also important.

5.7. Technological barriers

The availability of appropriate processing technology is often a key barrier in practicing for a circular economy. The technological specification of the circular product is one of the significant factors to review.[159] The accessibility of the right technology at every production stage of the circular products is essential to introduce the circular product in the market. The absence of technological innovation also restricts the supply of high-quality recycled fibres with affecting price competition.[160] Furthermore, there is an absence of an information exchange system and there is a poor distribution system of data among suppliers to put the

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[156] Cf. Online: Preston (2012); Rosen (2016)
[157] Cf. Online: Kang & Wimmer (2008)
[158] Ibid., 4.
[159] Cf. Online: Kirchherr et al. (2017)
[160] Cf. Online: Office for Social Responsibility of the China National Textile and Apparel Council (2020)

supply chain together; there are also too few large-scale technological demonstrating projects available in the current industry.[161]

5.8. Lack of awareness

A greater number of consumers are getting concerned about social, environmental and economic issues and consequently are willing to act on these concerns.[162] According to the new "cross-European survey" customers are happy to pay for a premium of between €2.22 and €4.43 on a T-shirt which was made sustainably. Even though, still only a few have joined this attitude according to a survey by 'IBM' and "Morning Consult" conducted on 1000 adults in Germany, Italy, Spain and UK. Considering a white cotton T-shirt, Germans are most willing to spend €3.92 more which is higher than others and UK would only pay the lowest additional amount of €2.12.[163] Thus, this result demonstrates that customers are willing to spend more but they lack awareness. Although, customers' awareness does not always express the shift into sustainable consumption habits due to various factors, for instance, convenience, affordability, availability and product performance.[164]

In current consumption trends, if a customer is offered with a product of shorter life but in less price or a product with a high price but in long-lasting lifespan, will choose the cheaper option due to "planned obsolescence"[165] a marketing strategy which needs to be adapted for the circular economy. Furthermore, there is a lack of motivation to transform consumption behaviour to concepts like re-using, leasing and using for a long time. Besides, the circular economy is still mostly implied as recycling which also has a negative implication for customers having low-grade fibre quality. Second-hand shopping trend seems to be getting popularity these days.

In connection with fashion designers, they often lack the understandings of sustainability challenges, solutions and practices to circular fashion. However,

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[161] Cf. Online: IMSA (2013)
[162] Cf. Online: Global Fashion Agenda & The Boston Consulting Group (2017)
[163] Cf. Online: Briggs (2020)
[164] Cf. Online: WBCSD (2008)
[165] Cf. Online: Taylor (2020)

even if they adopt the idea of a circular economy, they sometimes struggle to select correct material and production techniques due to complexities in large companies.[166]

6. Possible solutions and practices

Based on the analyzed literatures as well as reviewing various articles and scientific studies from different sources, several potential solutions with real-life situations to overcome the aforementioned challenges are analysed. These are further analyzed below.

6.1. Beginning with signature materials

Raw materials in the clothing industry do matter, because of their remarkable influence across the supply chain. Varieties of goods are booming in the clothing industry. A wide range of fibres and additives are being introduced every year which makes a product's development more demanding. The selection of the right fibre and other materials selection is one of the main drivers to achieve sustainability without compromising product performance which will lead to a more circular economy.[167] The key here is to break these materials' complexity, design out the leakage points by beginning research and develop one specific material or more signature materials to get pure materials that are more demanding in a circular economy.[168] It will be much easier for a different player to cooperate on specific materials across industries. Verifying the ideas of signature products, the stakeholders can then arise the solutions to second "high potential" items for a product.[169] This should be easier and quicker than trying on all materials at once. For example, one can start with cotton fibre since this is the most common type of material used to make the fabric that is ultimately used to make T-shirts. It is a well-established material in the clothing industry with high-volume recycling in practice, but with purity challenges like it suffers from quality loss and contamination during recycling.

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[166] Ibid., 1.
[167] Cf. Online: Innovation in textiles (2020)
[168] Ibid., 10.
[169] Ibid., 10.

Then as a second “high potential” material, one can start with polyester since it is a popular option for retailers and manufacturers and used in high volumes which currently lacks proper solutions to reuse. In contrast, as in “intimate blending” like a ratio of polyester and cotton blend, because of their differences in their strength and weakness, it makes them a perfect combination.[170] Also, by adding the stronger polyester in the yarn composition, the product life should be extended. On the other hand, since, currently there are no dissolving or extraction techniques available in blended fibre, thus emphasizing more on large-scale implementation of chemical recycling would be other ways to get to circularity.[171]

Bio-based fibres are achieving encouragement as alternative material since there are significant improvements in the level of energy and material use as well as resource recycling in using them.[172] Waste crop, bamboo, hemp, marine biological resource are some primary sources of bio-based fibres; more of this type of fibres’ varieties with their applications are shown in table 7 below.

Fibre varieties		**Applications**
New solvent spun cellulose fibre	Lyocell	Since cotton is a cellulose-based fibre and cannot be reproduced into its original superstructure after use, it can be converted into a dissolving pulp and then regenerated into a new textile fibre for example lyocell. It is used in casual wear and underwear.
New resource regenerated cellulose fibre	Bamboo or hemp pulp regenerated cellulose fibre	The bamboo pulp is made in fibre wet spinning from bamboo cuts; hemp pulp is made from jute and kenaf; both are suitable for close-fitting fabrics and home textiles.

[170] Cf. Zubair (2020)
[171] Cf. Online: EURATEX (2020)
[172] Cf. Online: China National Textile and Apparel Council-CNTAC (2020)

	Banana fibre	This fibre is produced from the by-product of the banana tree and it can be considered a sustainable option.
	Pineapple leaf fibres (PALF)	The pineapple leaf fibre is from the by-product of pineapple cultivation and it has applications in textile, sporting products, bags, automobiles, cabinets, mats and so on. Some of the fast-fashion brands like H&M and Hugo Boss are using it as a sustainable material.
Bio-based degradable synthetic fibre	Polyactic acid (PLA) fibre	The fibre uses starch and sugar crops to create lactic acid and it is then turned into a fully bio-degradable synthetic fibre through polymerization and spinning technology.
Bio-based non-degradable synthetic fibre	Polytrimethylene terephthalate (PTT) fibre	Non-food items like casava starch and glycerin are the raw materials to manufacture this fibre and is commonly used in T-shirt, jeans, swimwear and carpet.
Marine bio-based fibre	Alginate fibre	This fibre is made from brown seaweeds and really helpful in producing highly absorbents wound dressing.
	Chitosan fibre	This fibre is made of waste (shrimp and crab shells) from the sea food processing industry. They can be used in textile for antimicrobial finishing, increasing colour yields and so on.
Biological protein modified fibre	Soybean protein fibre	This biological protein fibre is a form of modified chemical fibre that can be made from soybean, wool, milk and silkworm
	Wool protein fibre	
	Milk protein fibre	

	Silkworm chrysalis protein fibre	and can be used in underwear and home textiles.

Table 7: Main bio-based fibres and their applications
(Source: China National Textile and Apparel Council-CNTAC, 2020 adapted from Li, 2016; Hildebrandt et al., 2020; Vade, 2015; Motte & Palme, 2018; Asim et al., 2015; Made Trade, 2019; Reflow, n.d)

6.2. Regenerative farming methods

Regenerative clothing holds the possibility to change the fashion industry by coordinating regenerative fibre production, which is a sort of farming methods.[173] Moving to regenerative farming methods for cotton and other cellulose-based fibres can increase soil-held carbon or organic matter, restore soil structure and promote biological activity, which ultimately contributes to long-term productivity.[174] This method can also introduce notable opportunities to reduce cost, the consumption of water and generate profits.[175]

As we know cotton is not an easy solution and it uses 16% of the world's insecticides.[176] The pesticides would then be able to get stored in the cotton which will get back to the food supply. In cotton production, the usage of non-renewable resources can be reduced by this regenerative method, which does not utilize synthetic fertilizers. There are cotton sustainability practices such as "Better cotton initiatives" (BCI) and 'Cotton Made in Africa" (CmiA) which encourage agricultural practices that reduce the use of insecticides and safeguard soil health.[177]

When considering buying a cotton based T-shirt, we usually take decisions based on colour, size and design but not on the capacity of soil to store or release carbon, from which that T-shirt's core material actually originates, that makes a huge difference. There is a new concept called "soil to soil" where it has been encouraged for fibre production starting with recyclable cotton, wool, alpaca, hemp, and flax on farms where the soil is sustainably managed.[178] Shifting from

[173] Cf. Online: HOLLYROSE.ECO (2020)
[174] Cf. Online: Lovins (2017)
[175] Ibid., 4.
[176] Cf. Online: Eco Voice (2020)
[177] Cf. Online: Cotton made in Africa (n.d)
[178] Cf. Online: Karas (n.d)

organic farming to regenerative agricultural practices would attract various funding opportunities also.[179] And by investing in regenerative farming methods, the regeneration will expand, which are supposed to create fashion as truly circular.

6.3. Responsible chemical management

The chemicals are like secret barriers in reaching circularity and as long as the textile industry does not encounter its relationship with chemicals at the primary stage, achieving complete circularity would be difficult. Ensuring effective chemical management in every stage of a product's life cycle would be like one step ahead toward circularity. Generally, circular chemistry can bring sustainability to the complete life cycle of chemical products which can optimize resource efficiency across the chemical value chain.[180]

Besides minimizing the consumption of resources such as chemicals, the circular strategy has the ability in producing new supplies of feedstock for the rising demand in the market. In 2011, the "Roadmap to Zero", a comprehensive campaign began as a group of brands to support the whole supply chain with its "zero discharge of hazardous chemicals-ZDHC" recommendations, platforms and strategies. Below figure 11 is an example of circular textile flow from fibre feedstock to clothing from "roadmap to zero".

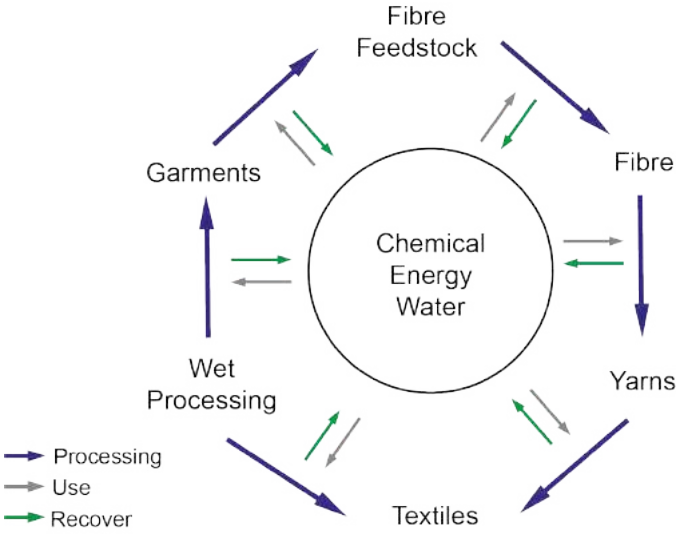

Figure 11: Example of circular textile flow from fibre feedstock to clothing

(Source: Adapted from "Roadmap to zero", 2020)

[179] Ibid., 4.
[180] Cf. Online: Keijer, Bakker, & Slootweg (2019)

To encourage efforts to optimise resources along each production stage in the fashion value chain, “roadmap to zero” are suggesting the below areas to work on in order to support the circular approach.

- **Input:** Blocking prohibited hazardous chemicals from entering the circular value chain by using their ZDHC tools and promoting the understanding the sustainable chemistry concepts.
- **Process:** Supporting traceability and accountability as well as providing guidance on the anticipated recovery of chemicals from the manufacturing process.
- **Output:** Allowing the transition to a more circular approach from single-use.

The followings are some possible frameworks of managing chemicals responsively within the textile industry.

6.3.1. Understanding the chemicals

The goal of understanding the chemicals here is to detox the textile industry using the right chemicals. Another important fact is, not all chemicals are harmful; at the same time, we also cannot be so sure about safe chemicals even if they are from an ‘organic’ or ‘natural’ source.[181] Therefore, since chemicals used in production can affect the circularity potential of finished products,[182] an important strategy for circular economy initiatives could be about understanding those chemicals first so that one can act accordingly.

6.3.2. Identifying and reducing the use of toxic chemicals

Reducing the use of toxic chemicals is important and an effective chemical management scheme can help to offset the use of these chemicals with greener substitutes.[183] In order to replace hazardous chemicals, textile manufacturers use 2 common formats of prohibited toxic chemical lists. The “Manufacturing Restricted Substances List (MRSL)” developed by ZDHC Roadmap to Zero

[181] Cf. Online: Michel & Kaelble (2020)
[182] Cf. Online: Accenture (2019)
[183] Cf. Online: UL LLC (n.d)

Programme, addresses hazardous substances used and released into the atmosphere during the manufacturing process.[184] On the other hand, the "Restricted substances List (RSL)" aims the chemicals from the finished product to assist regulatory compliance to product quality requirements. For example, REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals).[185,186] There is another organization called the "Apparel and Footwear International RSL Management" working group, whose aim is to reduce the use and effects of hazardous chemicals.[187]

The key step here is to limit the use of hazardous chemicals within the clothing manufacturing industry. ZDHC Roadmap to Zero Programme launched a new version 2.0 ZDHC MRSL chemical Guidance Sheets in 2019. Below table 8 attempts to show a number of restricted chemicals, which may be found in a T-shirt as well as the conformance guidance as per ZDHC MRSL version 2.0. This conformance guidance includes a chemical formulation limit, at the same time, bans the "Intentional use" of the restricted chemicals.

Restricted Chemicals		**Formulation Limit**
Alkylphenol Ethoxylates (APEOs) **Used in:** Spinning oils, scouring agents, detergent and softeners	- Nonylphenolethoxylates (NPEO) - Octylphenolethoxylates (OPEO)	500 ppm
Heavy Metals **Used in:** Various pigments and dyes.	- Antimony	Dyes 50 ppm/ Pigment 250 ppm
	- Cadmium (Cd)	20 ppm (50 ppm for pigments)
	- Copper	Dyes 250 ppm
	- Chromium	Dyes and Pigments 100 ppm
	- Lead (Pb)	100 ppm
	- Zinc salt	1000 ppm

[184] Cf. Online: Roadmap to Zero (2016)
[185] Ibid.
[186] Cf. Online: Chem-MAP (2018)
[187] Cf. Online: AFIRM group (2020)

Amines from azo dyes **Used in:** Various pigments and dyes containing azo bond (-N=N-)	- 3,3-dimethoxylbenzidine - 4-chloroaniline - 4-aminoazobenzene - o-anisidine	150 ppm
Phthalates **Used in:** Plastisol ink for printing on fabric surface, detergents, lubricating oils	- Di-iso-decyl phthalate (DIDP)[5] - Di(ethylhexyl) phthalate (DEHP)[5] - Di-isononyl phthalate (DINP)[5] - Bis (2-ethyl(hexyl)phthalate	Sum of substances 5 = 250 ppm
Organotin Compounds **Used in:** Plastisol prints, plastic trims, biocide and pesticides.	- Tributyltin (TBT) - Triphenyltin (TPhT)	5 ppm
	- Dibutyltin (DBT)	20 ppm
Volatile Organic Compounds (VOCs) **Used in:** chemical preparations, product cleaning process, screen print inks, plastic trims.	- Benzene	50 ppm
	- Xylene	500 ppm
Formaldehyde **Used in:** Printing and also in finishing process to give certain qualities, for examples, wrinkle and crease resistance in finished product.		There is no permitted usage level mentioned till now in ZDHC MRSL version 2.0, but they intend to put regulation on the acceptable levels in their next version. However, the intentional use of this chemical compound is currently prohibited.

* ppm (parts per million) mass of chemicals per unit volume of water.

Table 8: Probable restricted chemicals in a T-shirt with use guidelines

(Source: Adapted from Brigden et al., 2013; Roadmap to Zero Programme, n.d; CDC, n.d; Brigden et al., 2012; Cargo Handbook, n.d; Fraser, 2018; European Union, n.d; Sutthivaiyakit, 2005; Patagonia, 2012; green river tech, 2000)

6.3.3. Chemical inventories

An inventory of the chemicals is required in order to track the chemicals which are used, carry out risk assessments, avoid excess supplies, and warn responsible personnel about possible risks.[188] At the same time, a sound chemical inventory system with environmental considerations will lead to good purchasing practices, which as a result will help to minimize material use and prevent excessive use of hazardous chemicals.[189]

6.3.4. Good Housekeeping

To limit the negative impacts of chemicals on the environment and people as well as to save cost, there are some suggested housekeeping activities that should be practiced.[190]

- Acceptable care and cleaning activities.
- Prevent chemical or untreated wastewater leaks and discharges.
- Promote work and health safety as well as energy conservation.

6.3.5. Traceability and transparency

Both transparency and traceability have often been troublesome across the entire supply chain but ensuring reliable traceability would offer the utmost transparency.[191] Typically, chemical formulations are a combination of several chemical ingredients which might contain unintended impurities or harmful substances. Chemical manufacturers only unveil regulated chemicals if these are above a certain limit, based on the type of chemical, between 0.01% to 1% of the entire concentration; and since, the amount of finished garment is usually high, this implies that the hazardous chemicals will possibly add up in the environment at the end and harm consequently.[192] Transparency to the chemical ingredients in chemical details is very much important.

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[188] Cf. Online: Partnership for Sustainable Textiles (n.d)
[189] Cf. Online: Alkaya et al. (2011)
[190] Ibid.
[191] Ibid., 46.
[192] Cf. Online: Fashion Positive (2020)

Blockchain, a specific type of digital database is being applied over various industrial settings including fashion companies, for example, Hugo Boss is using this technology to upgrade traceability and transparency within their supply systems.[193] Additionally, appropriate certifications will encourage with improved transparency, for example 'GreenScreen' for safer chemicals and "Cradle to Cradle" certifications that require full disclosure and documentation of the ingredients used in a product.[194]

6.3.6. Wastewater management

It is evident that in order to survive, humans and other living organisms require water, besides that, water is also necessary for human's economic activities. Most importantly, in 2010, water and sanitation were perceived as human right in the general assembly of the United Nations.[195] But, failure to treat wastewater efficiently poses significant challenges. Fast and foremost, a good wastewater management system starts with avoiding dangerous chemicals from entering water followed by proper legitimate treatments. The composition of wastewater from chemical use depends on certain factors, such as the type of fibre, fabric construction, textile finishing process, type of chemicals used in the process and type of treatment strategy applied; therefore, wastewater must be treated in such a way, so that it does not harm human and environment.[196] Following approaches for wastewater treatment are already in practice in a beneficial manner for both environment and the economy.

6.3.6.1. Industrial treatments methods of wastewater from textile

Dyes are organic compounds utilized to dye yarn, fabric or even complete garment and are usually harmful as well as soluble in water.[197] There are around 200,000 tonnes of dyes are lost in effluents every year while operating dyeing and finishing processes due to lack of efficiency.[198] It is difficult to removed dye from contaminated water with the help of conventional treatment techniques due to

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[193] Cf. Online: Brun, Karaosman, & Barresi (2020)
[194] Ibid., 4.
[195] Cf. Online: United Nations (2010)
[196] Ibid., 47.
[197] Cf. Online: Elumalai et al. (2014)
[198] Cf. Online: Ogugbue & Sawidis (2011)

dyes resistance to exposure to light and water.[199] Fortunately, there are some methods like photochemical degradation, adsorption, flocculation, ozone treatment, electrocoagulation, and so on have been widely used to remove dyes from aqueous solutions.[200] There is another water purification process called reverse osmosis (RO) which can be used to recover around 80% of textile dyehouse effluent.[201]

I. **Physical Methods:**

There are some frequently used physical methods such as absorption, filtration, irradiation and ion-exchange.[202] Because of high dyestuff removing capacity and low cost, these processes are widely used in the industry.[203] Adsorption method to exclude toxins from effluents could be a good option because this procedure may generate treated wastewater of good-quality.[204]

II. **Chemical Methods:**

Physical methods are not always appropriate in order to remove dyes entirely, it requires additional care to remove solid waste. Here, chemical methods are used because of their conveniences. A common chemical process is “flocculation and coagulation” which is used to extract the organic pollutant.[205]

III. **Biological Methods:**

Comparing to physical and chemical methods, biological approaches are more green strategies in order to remove dye from textile effluent at minimum expense and time.[206] Industrial wastewater contains numerous microorganisms like microbes, bacteria and yeasts who use pollutants as their ‘food’ and as a result, the pollutants get broken down into small and

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[199] Cf. Online: Karthik et al. (2015)
[200] Ibid.
[201] Cf. Online: Pandey et al. (2020)
[202] Cf. Online: Gosavi & Sharma (2013)
[203] Cf. Online: Mckay, Porter, & Prasad (1998)
[204] Cf. Online: Tetteh et al. (2019)
[205] Ibid.
[206] Cf. Online: Banat et al. (1996)

less complex molecules which makes these pollutants easily detachable from textile effluent.[207]

6.3.6.2. Wastewater treatment by agricultural by-product.

Apart from the above methods, environment-friendly utilization of by-products from agriculture would be useful in treating wastewater due to their accessibility and performance in removing numerous undesirable pollutants.[208] The Pongamia pinnata tree's bark and banana peels can be applied for the removal of heavy metals for example cadmium and lead from effluents.[209] It is also possible to use peels of citrus lemon to remove anionic dyes for example "Methyl Orange" and "Congo Red" and garlic peel to remove "Methylene Blue" from aqueous solutions.[210]

6.3.7. Recover, Reuse and Reduce

The circular economy approach can be applied in the wastewater treatment sector[211] by saving, recovering and reusing resources from wastewater, which will lead to environmental impact reduction.[212] Today's innovations in wastewater treatment can make the water reusable by human, even the treated water may be drinkable as well. But the most widely cited hurdle is what has been called the "yuck factor", a mental fact that has strong implications on decision making to accept or refuse a specific use of recycled water.[213] Nonetheless, considering the value of water and substances from effluents as a resource, there is a wide range of options to apply the circularity approach.[214] An example could be the "Honouliuli wastewater treatment plant (WWTP)" facility, established in Oahu, Hawaii, which can handle 26 million gallons of wastewater per day, generate 12 million gallons of recycled water per day and supply to golf courses of Oahu island, agriculture and cooling towers in the industry.[215] Some current practices and developments in

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[207] Cf. Online: Kiran et al. (2020)
[208] Cf. Online: Sulyman (2017)
[209] Ibid.
[210] Ibid.
[211] Cf. Online: Guerra-Rodríguez et al. (2020)
[212] Cf. Online: Salgot & Folch (2018)
[213] Cf. Online: Po et al. (2005)
[214] Ibid., 50.
[215] Cf. Online: Honolulu Board of Water Supply (2003)

recovering and reusing as well as reducing the consumption of resources are shown in table 9 below.

Recover	▪ Lanoline, an organic and renewable raw material may be recovered from the effluents obtained during cleaning the wool. Also, the grease recovered from the woollen industry can be sent to automobile industries. ▪ A nutrient, zinc can be reclaimed from the waste generated in the viscose rayon process with the help of ion exchange, precipitation and floatation. ▪ Salt recovery from textile dyehouse could bring another opportunity like reusing this salt in dyeing and finishing plant.
Reuse	▪ The common uses of recovered wastewater are agricultural, industrial, urban, environmental or purposes. ▪ As an on-site reusing strategy, rinse water and wash water from bleach baths can be reused. ▪ With the help of the “carbon adsorption” treatment method, carpet mills can cycle 80% of about 350 gpm (gallons per minute) of wastewater back to the mill. ▪ The residual material, called sludge is a by-product of a wastewater treatment facility that can be used as fuel.
Reduce	▪ To reduce water consumption there are machines or related equipment for dyeing, scouring, bleaching and washing which will eventually save energy. ▪ Furthermore, using solar energy to heat water for dyeing could help saving other non-renewable energy. ▪ Development in biodegradable enzymes can help reducing water consumption since it dissolves in the softening process and washed off gradually. ▪ There are developments in salt-free dyeing in cotton with reactive and direct dyes which can save water and process cost. ▪ Using digital inkjet printing for textile printing could help reducing water and energy consumption as well as cost.

Table 9: Resource recovering, reusing, and reducing the consumption

(Source: Adapted from Rearick., 1995; Guerra-Rodríguez et al., 2020; Alkaya et al., 2011; Pandey., 2020; Kumar et al., 2020; Singha et al., 2012; Gupta., 2001)

6.4. Sustainable trends in dyeing

As the textile dyeing industry is considered as one of the major water consumers and the traditional technique needs more water, it then produces more wastewater.[216] In order to dye 1 ton fabric, it requires approximately 200 tonnes of fresh water.[217] Due to growing development in dyeing technologies, there are some sustainable options available which are briefly described below.

6.4.1. Natural dyes

A gift of mother nature is a natural dye, assumed to be not detrimental to the environment, which makes it so fetching these days. It is forecasted that the sales value of natural dyes will hit $5 billion by 2024. Natural dyes are generally biodegradable which means effluents from using these dyes are easily acceptable.[218] Naturals dyes are made from several natural sources; a brief detail with few examples is given in below table 10.

	Sources	**Achievable colours**
Animal based	Kermes insects(red)	Red
	Beetles from Cochenille plant	Carmine Red
	Sea snail (violet)	Violet
Plant based	Grape leaves	Yellow, Green
	Turmeric	Yellow
	Logwood	Deep Purple
	Onion	Brown, Orange
	Blueberry	Purple
Mineral based	Red lead	Red
	Malachite	Green
Microbial and Fungal based	Lichens	Purple
	Penicillium species	Yellow, Red, Orange

Table 10: The sources used for natural dyes

(Source: Adapted from Deutsche Welle – DW, 2019; Merdan et al., 2017; Lagashetti et al., 2019; Botanical colors, n.d; Verma & Gupta, 2017)

[216] Cf. Online: Hu et al. (2018)
[217] Cf. Online: The Conscious Challenge (2019)
[218] Cf. Online: Deutsche Welle – DW (2019)

Natural dyes are not always sustainable; they need plenty of areas of fertile lands, sometimes even more water than synthetic dyes need. More recycling and better waste management and most importantly continuous innovation may lead us to our precious answers we are looking for.[219] A start-up clothing company "ZEST N ZEAL" sells organic cotton T-shirts dyed from natural sourced dyes such as fruits, leaves and regenerative vines without any chemicals.[220] This company is also claiming that the water they are using to dye the fabric, the generated water is being reused for irrigating coconut plantations.[221] A German-based company 'Dr.Petry' specialised in the development and production of textile auxiliaries, developed a new range of pigments called 'PERICOLOR ECO' that are mainly made from mineral sources and they are not water-soluble and resistant to chemicals.[222]

6.4.2. CO2 dyeing - waterless

The Dutch company called 'DyeCoo' introduced a textile dyeing solution which does not use any water, instead, it uses carbon dioxide (CO_2). This method is being called "CO_2 dyeing" or "waterless dyeing". It has the potentiality to be a sustainable, efficient and profitable process; that is because this technology does not have to process water to make it chemical-free.[223] This dyeing technique is currently limited in polyester fabric and developments are going on so that nylon fabric can also be dyed in the same machine. To dissolve dyestuff, carbon dioxide (CO_2) is heated and pressurised to make it supercritical carbon dioxide (sc-CO_2) which is a form in between liquid and gas. The carbon dioxide (CO_2) which are already used can be reused too up to 95%. Moreover, the dyeing method uses less dyestuff and less energy due to using zero water.[224] Efficient use of dyeing with no wastewater treatment makes this method economical as well as provides geographical freedom to set up this dyeing facility any water stressed region.[225] Overall, this supercritical carbon dioxide (sc-CO_2) is an encouraging alternative to

[219] Ibid., 52.
[220] Cf. Online: Ethical revolution (n.d)
[221] Cf. Online: Zest N Zeal (2018)
[222] Cf. Online: DR. PETRY (n.d)
[223] Cf. Online: DyeCoo (n.d)
[224] Cf. Online: European Commission (2019)
[225] Cf. Online: European Union (2019)

current dyeing practice for its identical colouration, economic influence and environmental advantages.[226]

6.4.3. Airdye

A California-based company 'Colorep' developed 'Airdye' technology that uses up to 95% less water, 86% less energy, and contributes 84% less to global warming than traditional dyeing and printing techniques.[227] The process works by transferring dye from paper to polyester fabric using a printing machine[228] with no post-production treatment.[229] The papers and dyes used in this method can also be reused.[230]

6.4.4. ColorZen

Colorzen introduced a pre-treatment process for the cotton fibre that gets cotton more responsive to dyestuffs. It allows the cotton to consume even more dye during the actual dyeing operation without using more water, toxic chemicals, and energy. With the help of this technology, a cotton garment is said to require up to 95% less chemicals, 50% less dye, zero salt, and 90% less water[231] and the water left after dyeing can be reused too.[232]

6.4.5. Dope-dye

Another environmentally friendly innovative method is dope dyeing which is also called "color spinning fibre" or "pre-spinning dyed fibre". In this process, colour is added into the spinning solvent then the fibres are spun to get the dyed fibre. That is why this process has great influence on the reduction of water and energy usage. It can also reduce carbon dye emissions. The fibre generated from this process is treated as a "Green Fibre". At present some synthetic and regenerated cellulose fibres can be prepared with the help of this dyeing technique.[233]

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[226] Cf. Online: Abate et al. (2020)
[227] Cf. Online: Kumar et al. (2010)
[228] Cf. Online: Hepburn (2015)
[229] Cf. Online: WRAP (n.d)
[230] Ibid.
[231] Cf. Online: Innovation Textiles (n.d)
[232] Cf. Online: Knitting views bd (2018)
[233] Cf. Online: CNTAC, Ellen MacArthur Foundation, & Lenzing (2020)

There is an issue with this process; fibre manufacturing factories are used to make colourless pure fibres, but since this requires various colour involvement, there is a matter of cleaning the factories, that is why dope dyeing is considered as a 'dirty' process what factories do not prefer to use. And this leads to higher "minimum order quantity" requirements which are about 10 tonnes. Therefore, fashion brands need to work on their buying decision while preparing colour-wise quantities every season, if they want their suppliers to use this technology.[234]

6.4.6. Additional breakthrough

- **Dyes from synthetic biology**

Synthetic biology is a scope of science that is evolving fast and has the limitless opportunities in the field of the textile dyeing industry. Producing dyes from naturally born bacteria has been treated as an alternative sustainable option to regular synthetic dyes and this option has the possibility to reuse raw materials in cheaper and faster ways by saving a lot of energy which can be adopted well into the circular economy.[235]

As an approach to eliminate the use of water and chemical in dyeing process in cost effecting way, a biotechnology company from the United Kingdom, introduced a synthetic biological approach where they use bacteria from nature to dye textile. At first, they collect bacteria from nature, and then by working on its 'DNA' sequence and getting the genes into an engineered microorganism they can produce colours. They use by-products from sugar production as the feedstock for the process. And for the dyeing process they use non-toxic, renewable chemicals and microorganisms to transfer and bind the colour in fibres with far less water than the traditional dyeing process needs.[236]

Researchers of the University of California are working on genetically modified dyes for denim. In this process, at first, a colourless organic compound called 'indican' is produced from a bacteria called 'E.coli', after that with the help of

[234] Cf. Online: Patterson (2020)
[235] Cf. Online: Georgakopoulou (2020)
[236] Cf. Online: Wright (2020)

the enzymatic treatment process the ‘indigo’ colour can be produced without any harmful chemical.[237]

In the future synthetic biology has the potentiality in advancing towards energy and chemical production and environmental protection.[238] This “living technology” even has tremendous possibilities for gaining control over the entire life cycle of bacteria, if we become successful in designing synthetic biology without upsetting our ecosystem.[239]

- **Dyes from textile fibres**

An Italy-based sustainable dyestuffs manufacturing company named ‘Offician+39’ prepared a dye range called ‘Recycrom’ in which they can make pigment dyes from recycled garments with the help of natural chemicals. Through a sophisticated production process, fibres are crystalised into pigment dyes in the form of an incredibly fine powder that can be used in both natural and mixed fibre. Which is a great initiative in the concept of reusing and recycling the clothing.[240]

- **Cationic cotton:**

Cationic cotton is a pre-treatment process for cotton to make it more suitable to allow dyes to bond with fibre which leads to dye, chemical, water, and energy utilisation more efficiently. Normally, raw cotton stays neutral or mildly negative-charged, but after this pre-treatment, the cotton becomes permanently positive-charged. Even though this process is already in use for several years, constant development is going on in order to find more sustainable ways to reduce water and chemical consumption.[241] A chemical company, ‘Dow’ developed new cationic chemistry named “ECOFAST Pure” for the technology of cationic cotton. This new treatment technique can consume 50% less water and dyes as well as and reduce dye times which

[237] Cf. Online: Mogilireddy (2018)
[238] Cf. Online: Synthetic Biology Leadership Council (2012)
[239] Cf. Online: Ginsberg et al. (2014)
[240] Cf. Online: Material connexion (2019)
[241] Cf. Online: Cottonworks (n.d)

leads to 40% less energy.[242] Furthermore, it does not generate any unpleasant smell once the treatment is completed.[243]

6.5. Bringing circularity in plastic packaging:

The simple concepts here are to design plastic packaging in a way it can be recycled without sacrificing its intended purpose and ensure a proper collection system to all points so that it can be recycled, reused, or even composted; these are further analysed below.

6.5.1. Choosing the right material

Design characteristics of plastic packaging need to be addressed wisely, for example, integrating pure “Low-density polyethylene”, recycled or compostable alternatives into the plastic packaging and ensuring the use of additional right materials. In general, manufacturers use inks on plastic packaging for warning and branding text as well as adhesive to close the bag. But ink can lead to ‘greyness’ during recycling which makes the process difficult to get a ‘transparent’ look, a key feature of polybag.[244] More eco-friendly and recyclability-oriented inks and adhesives would contribute to achieving success in the recycling process. A pilot plant was set up by a technical company named ‘CADEL Deinking’ where they developed a unique method to extract printed ink from the plastic surface without modifying it.[245] There are some associations such as the “Plastics Recyclers Europe (PRE)” as well as the “Association of Plastic Recyclers (APR)” introduced some similar design guidelines for plastic packaging which are as follows.

- The Main body of packaging should be in “Linear low-density polyethylene-LLDPE” or only in “Low-density polyethylene-LDPE”.[246]
- Use water-soluble adhesive which can be dissolved at 40°C to 60°C.[247]

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[242] Cf. Online: DOW (n.d)
[243] Ibid.
[244] Ibid., 10.
[245] Cf. Online: Cadel Deinking (n.d)
[246] Cf. Online: Plastic Recyclers Europe (2019)
[247] Ibid.

- Need to avoid using inks[248] or at least the inks should be non-toxic and non-bleeding to avoid contamination.[249]

6.5.2. Preferable option - Recycling

Even though plastic recycling has some limitations, this option seems to be more preferable choice these days. However, first and foremost, in order to obtain the title 'recyclable', there are several requirements imposed which relate to plastic packaging. The Association of Plastic Recyclers (APR) and Plastic Recycler Europe (PRE) published below 4 conditions as recommendations to declare plastic packaging as recyclable plastic packaging.[250]

- The product must be produced from plastic that is processed for recycling, has commercial value, and is supported by a scheme required by legislation.
- The products are sorted into specified phases for recycling purposes.
- Products can be processed and recycled with commercial recycling methods.
- The recycled plastic turns into raw material that can be used to producing new goods.

Solid waste treatments basically depend on the technologies like landfilling, incineration, and recycling.[251] 'PlasticsEurope' called for a ban on landfilling plastic to attain the circular economy in plastics where several nations are planning to execute this ban.[252] Therefore, landfilling here would be playing a minor role. In terms of recycling, a Brussels-based NGO "Zero Waste Europe" showed 4 benefits as below to choose recycling over incineration technology.[253]

- Recycling spares energy
- Recycling is more adaptable and effective
- Recycling is more profitable

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[248] Cf. Online: Recyclass (2017)
[249] Ibid.
[250] Cf. Online: Plastics Recyclers Europe (2018)
[251] Cf. Online: Geyer (2020)
[252] Cf. Online: PlasticsEurope (2018)
[253] Cf. Online: Zero Waste Europe (2017)

- Recycling creates more job

Recycling is seen as an influential way to ease the use of commodity plastic and environmental impacts from the ever-growing production of plastic.[254] The most common method for plastic waste recycling is mechanical recycling, also known as secondary recycling which can recover the solid waste for reuse.[255] A study implies that adequate amounts of separated collected plastic wastes can be effectively recycled where the recovered material can substitute the virgin polymer (the purest form of plastic).[256] But, the problem lies within quality, since the produced quality suffers from a significant quality loss, a downcycling.[257] these downcycled polymers, however, can again be used to make different types of product and it is also possible to make the original product using the mixture of recycled material and virgin material.[258]

A circular economy desires suitable innovations such as chemical recycling to recycle a huge amount of plastic packaging wastes effectively.[259] Chemical recycling can provide identical products to the products that have been replaced[260] as well as can turn plastics into new industrial feedstocks for further use.[261] With regard to process engineering, chemical recycling has less purity requirement in comparison with mechanical recycling.[262] In addition, a study showed that all chemical recycling procedures could mitigate the consequences of global warming and demand for limited fossil resources if only the input of plastic packaging wastes can be sorted in the first place.[263] There are different types of innovations in chemical recycling being advanced for recycling plastic packaging into virgin quality polymers, for example;

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[254] Cf. Online: Geyer et al. (2015)
[255] Cf. Online: Al-Salem, Lettieri, & Baeyens (2009)
[256] Cf. Online: Michaud et al. (2010)
[257] Cf. Online: Hong & Chen (2017)
[258] Cf. Online: O.Berk (2018)
[259] Cf. Online: Rahimi & García, (2017) as cited in Meys et al. (2020)
[260] Ibid.
[261] Ibid., 10.
[262] Cf. Online: Lechleitner et al. (2020)
[263] Ibid.

- ‘Pyrolysis’ or ‘gasification’ can break down the material at raised heat in the absence of oxygen and produce some sort of oil; and this type of oil can also be used to produce new virgin quality polymer.[264] The World Economic Forum, The Ellen MacArthur Foundation, and the McKinsey & Company published a report where this recycling technology is anticipated to have the potentiality to bring closed-material loop for unrecyclable packaging items.[265]
- “Solvent-based chemical recycling”, where the solvent is used to extract the polymer to reuse.[266]

Unfortunately, these technologies are still in the early development stage[267] and some are expensive too.[268] Therefore, it is hard to determine now if these could be the solutions we need to bring full circularity in plastic packaging. In the future, though, it is worth providing more attention to the broader range of chemical recycling in order to recover higher proportions of mostly mixed plastic waste and thereby prevent material getting into incineration and landfilling.[269] Close collaboration with entire value chain and brands as well as governments involvement is necessary.

6.5.3. More viable options

Besides using plastic packaging waste as a resource to reuse through recycling, focusing on using less plastic material would be feasible but it will lead to thinner polybags and in reduced size.[270] An American clothing brand, ‘Patagonia’ investigated about reducing the size of polybag, turned out, they could save plastics of 50,000 pounds each year; but since the reduced size in polybag might affect the appearance of the folded garment, they suggested to work on garment folding guidelines to get a better outcome.[271] This practice might be useful if the polybag still can maintain its protective features also. A premium lifestyle clothing brand ‘prAna’ already started practicing this method by adapting their folding

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[264] Cf. Online: McKinlay (2019)
[265] Ibid., 4.
[266] Ibid., 10.
[267] Ibid., 10.
[268] Ibid.
[269] Cf. Online: Lechleitner et al. (2020)
[270] Ibid., 10.
[271] Cf. Online: Cohen (n.d)

guidelines, in addition to that, they tie the garments with raffia cord (fibre from frond leaf) as shown in figure 12, to keep the garment in good shape across the product's entire journey in the supply chain.[272]

Figure 12: The folded garment of prAna, tied with a raffia cord
(Source: SALABER, 2020)

Another way could be eliminating the use of individual polybag per garment and instead pack multiple garments in single master polybag (a bigger version of single/individual polybag) as shown in below figure 13 and 14. A clothing brand 'Everlane' trialled putting 50 T-shirt in a master polybag instead of packing each of them in a single polybag which is a good initiative but as soon as the master polybag was unpacked in the warehouse, they were struggling to keep garments clean,[273] especially in online platform this problem happens now and then. Introducing effective product handling and distribution system in every collection point like, factory finishing department, as well as retail warehouse, distribution centre and retail store would reduce these problems.

Figure 13: Each garment is packed individually
(Source: Epyllion Style Limited, 2021; Munford, 2020)

[272] Cf. Online: Caputo (2016)
[273] Cf. Online: Segran (n.d)

Figure 14: Several T-shirts packed in one master polybag
(Source: Epyllion Style Limited, 2021)

In contrast to using less polybag, what if the clothing industry decides to remove this plastic packaging item from its entire supply chain; it might also be a great step towards circularity. But there is a possibility to face 'mould' problem on garment because of not having sealed polybag. Shipping the polybag-free garments in more durable and reusable containers and maintaining special environment during the journey from factory to brand's distribution centre could be a sustainable solution.[274]

Based on the strategic plan for a circular economy, the European Commission outlined that by 2030, all plastic packaging in the European market needs to be reusable or recyclable and the commission will focus on developing regulatory action for the growing market for plastics with biodegradable properties.[275] The reusable polybag option may be more useful in the future, where there are local manufacturing sites close to end markets with high return rates of plastic polybag from end customers.[276] Regarding biodegradable plastic, it has the same features as traditional plastic and provides further advantages, for example, reduced carbon footprint.[277] Besides opportunities this biodegradable plastic brings, there are risks also. Due to lack of appropriate conditions not all biodegradable plastic

[274] Cf. Online: Szaky (2014)
[275] Cf. Online: European commission (2018)
[276] Ibid., 11.
[277] Cf. Online: Barker (2018)

fully degrades[278] and some causes problem in the recycling process.[279] Conducting more research, educating consumers,[280] and promoting investment and innovations may eventually prepare this promising option for plastic packaging in future.[281]

6.6. Self-assessment tools

To achieve a circular economy, first, textile industry needs to measure its actions toward circularity. Building and following the circularity indicators or KPIs can help to identify its hidden strength and vulnerability by providing market information, supporting to make sourcing decisions, managing resources, and creating accountability over the entire supply chain; and then textile industry can identify and evaluate circularity performance.[282] Some available self-assessment tools are described below which may offer practical potential to achieve circularity.

6.6.1. Higg Index

The Higg Index was initiated by a non-profit corporation, the Sustainable Apparel Coalition (SAC), formed by a group of retail fashion brands, industry affiliates, and trade associations. The aim of this initiative is to provide a suite of structured sustainability assessment tools to fashion brands, retailers, and other facilities.[283] Based on the sustainability performance, Higg Index will assess and include the scores for the company or the product which enable companies to take the right measures for the improvement of environmental and social problems across the entire value chain,[284] which may lead to a great advancement towards a circular economy.

Circularity could be a fundamental approach to ensure transparency and minimize the use of limited resources and to achieve that Sustainable Apparel Coalition (SAC), Global Fashion Agenda, and Federation of the European Sporting Goods

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[278] Cf. Online: Bell & Cave (2011)
[279] Ibid.
[280] Ibid., 10.
[281] Ibid.
[282] Ibid., 4.
[283] Cf. Online: Sustainable Apparel Coalition-Press Release (n.d)
[284] Cf. Online: Sustainable Apparel Coalition (n.d)

Industry (FESI) set up a "Policy Hub on Circular Economy".[285] One of the key recommendations of this Policy Hub is that the EU policymakers need to support the capability of Higg Index in designing strategies to ensure a circular economy in textile industry.[286] The Higg Index is divided into three modules: The Brand, A Facility, and A Product Module, that are combination of a suite of tools such as:

a) The Higg Materials Sustainability Index (MSI): the concept of MSI was initially developed by Nike by following years of research and study. Sustainable Apparel Coalition (SAC) adopted it for the Higg Index.[287] The Higg MSI calculates environmental impacts of materials based on a large amount of various information related to material from the fashion and home textile industry.[288]

b) The Higg Product Module (PM): The Higg PM tool is a life cycle measurement tool that offers applicable information to determine the effectiveness of products and supply chain in 5 impact categories:
   - Global warming potential
   - Water scarcity
   - Eutrophication
   - Fossil fuel resource depletion
   - Chemistry

c) The Higg Facility Social & Labour Module (FSLM): The Higg FSLM allows facilities to ensure safe and fair social labour conditions of workers in the value chain by evaluating facilities' performance. It can help reducing a lot of costs involved in auditing the facilities if one follows the scored assessment and works accordingly to improve. The impact areas the Higg FSLM assesses are:[289]
   - Working hours
   - Compensation
   - Worker treatment and advancement
   - Empowering people and communities
   - Health and safety
   - Worker engagement
   - Value chain performance
   - Termination

[285] Cf. Online: European Union (2019)
[286] Cf. Online: Policy Hub (2019)
[287] Cf. Online: Higg Index Product Tools (n.d)
[288] Cf. Online: Circular Berlin (n.d)
[289] Cf. Online: Sustainable Apparel Coalition & Outdoor Industry Association (2016)

d) The Higg Facility Environmental Module (FEM): The Higg FEM is a sustainability assessment tool that informs brand, retailer, and manufacturer about their facility's environmental performance. The Higg FEM assesses:[290]

- Environmental management systems
- Energy use
- Greenhouse gas emissions
- Water use
- Wastewater
- Emissions to air
- Waste management
- Chemical management

e) The Higg Brand & Retail Tool (BRM): The Higg BRM tool measures the efficiency of brand and retailer throughout their social as well as environmental parameters[291] by analysing the following life cycle phases:[292]

- Management system
- Product
- Supply chain
- Packaging
- Use and end of use
- Retail stores
- Offices
- Transportation
- Distribution centres

6.6.2. Circulytics

Circulytics, introduced by the Ellen MacArthur Foundation together with their global partners, is a complete circularity analysis tool that helps businesses to calculate their circularity and shows to what degree they have accomplished circularity through their entire business operations by highlighting ways to better integrate circular processes further. [293] As described below, the Circulytics scoring system works by applying a 3-steps weighting technique which comprises 36 sustainability indicators in the total assessment. [294,295]

- 1st step: sustainability indicators are chosen and then used them to calculate a weighted average for 7 main themes:

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[290] Cf. Online: Sustainable Apparel Coalition (n.d)
[291] Cf. Online: Lössl (2020)
[292] Cf. Online: Sustainable Apparel Coalition (n.d)
[293] Cf. Online: Ellen MacArthur Foundation (2020)
[294] Cf. Online: Morone & Yilan (2020)
[295] Cf. Online: Ellen MacArthur Foundation (2020)

1) Strategy and planning
2) People and skills
3) Systems, processes, and infrastructure
4) Innovation
5) External engagement
6) Inputs
7) Outputs

- 2nd step: Another weighted average is calculated for 2 category-level ratings:
    1) Enabler: measures the future circular potential of a company with qualitative indicators for instance, how much effort is being made to be more circular, whether the company is ensuring training and whether invests sufficiently.
    2) Outcomes: measures how circular a business is currently by evaluating for example, whether a company can procure raw-materials and design products that support circular economy.

- 3rd step: Finally, a single representative Circulytics score is produced.

According to Ellen MacArthur Foundation, more than 30 companies have already been evaluated by this tool and more companies are accepting this approach in order to calculate their circularity.

6.6.3. Made-by

The Made-by is an environmental benchmarking tool launched by Brown & Wilmanns Environmental (bwe), particularly for fibres. It analyses the environmental impact of the most widely used fibres in garment manufacturing industry. This tool measures based on 6 parameters:[296]

1) Human toxicity
2) Eco-toxicity
3) Energy

[296] Cf. Online: Brown & Wilmanns Environmental (n.d)

4) Water
5) Land

The Made-by also developed a progress monitoring tool called “MODE Tracker” which offers a holistic overview on issues what fashion industry can use. It evaluates progress in areas such as packaging, transport, product, and production.[297]

6.7. Collection and sorting for reuse and recycling

The clothing finished product collection system has been set up for quite a long time and is a very much demonstrated case of circular business model, in which product and material life is prolonged through reuse or recycling. Clothing collection bins at stores and recycling points are getting appreciated these days in many countries. The Garment Collection Program is a global initiative by some renowned clothing brands like H&M, C&A, Kappahl, Nudie! Jeans, Lindex, and so forth. C&A started their in-store and online take-back program known as “we take it back” by awarding consumer with a 15% discount on next purchase after the used garment collection.[298] As reuse and recycling initiative, in 2019, H&M group collected 29,000 tones of cloths which is comparable to 145 million pieces of T-shirts. H&M collects cloths in stores from customers which intends in three phases – Re-wear, Reuse, and Recycle.[299] As a commitment to circular business approach, Lindex offered cloths collection program in its all stores by training their design, buying, and production team in circular product designing.[300]

After the use phase, the life of clothing or material is not finished, they can be collected and transported to recycling plants to be sorted. The best quality items of them can therefore be sent to a second-hand shop for resale or maybe to charity shops and the rest of the items can be recycled or re-manufactured to add value and resale as fashionable clothing; implementation of this scenario would require allegiance from government, customers and new technology.[301] Additionally, It is

[297] Cf. Online: Grevinga et al. (2017)
[298] Cf. Online: C&A (2018)
[299] Cf. Online: H&M (n.d)
[300] Cf. Online: Lindex (2020)
[301] Cf. Online: Well dressed (2006)

important to pay attention to seeking cheaper ways of reusing and recycling to make these practices acceptable to customers. Moreover, precise sorting requires a great deal of accuracy. It is not that hard to recognize a T-shirt from a sweatshirt, but with regards to a quality piece of clothing, explicit inquiries must be taken into consideration, for example, type of T-shirt, fashionable or outdated model, for female or children and if the T-shirt is of premium quality or low quality. On the other hand, concerning clothing waste, there are three European pilot projects are introduced: the 'Fibresort' (Holland), 'SIPTex' (Sweden), and 'Resyntex (Germany) which are currently sorting large volumes of mixed product or material waste according to fibre type and colour.[302] Also, 'BlockTexx' a clean technology, Australia-based company is leading a global movement toward the circular economy by recovering polyester and cellulose fibre from textile and clothing and turning clothing waste into sustainable products.[303]

In terms of plastic packaging, there is a need for an innovative collection system at all points where polybag waste is produced, particularly at fashion brands' distribution centers and retail stores. A proper collection scheme in plastic packaging from every point can assess the level of contamination present in the collections entering into the sorting facility, which will also be helpful in plastic recycling process later on.[304] Besides, that, ensuring individual brand's responsibility can enhance this collection, sorting, and recycling practice. The North Face initiated a recycling scheme in partnership with a recycling company called 'Terracycle' to actively collect and recycle the polybags which they are consuming and discarding.[305]

6.8. Reverse network

The potential value of the circular economy is not always only about recycling the used materials, this value is covered within the maintenance, reuse, restoration, and remanufacturing of the materials and products; therefore, these reverse setups are equally important, and companies can master the system

[302] Cf. Online: Messe frankfurt (n.d)
[303] Cf. Online: BlockTexx (n.d)
[304] Ibid., 58.
[305] Cf. Online: Szaky (2014)

administration of complex and multitier supplier networks to apply it in post-usage value streams across various reverse cycle partners.[306] In regard to mapping the system for one product, companies need to be careful to evaluate cycles which would bring most benefit. Figure 15 below, represents a very simplified layered supplier network for a T-shirt model and draws out the unique choices for the reverse cycle. Now, it needs to be decided whether it is better to use or sell the whole T-shirt as a used product or use its components to make a new one, because making a new t-shirt with another t-shirt component may not be feasible currently. Conversely, if all element ought to be sent to the factory for extracting fibre from it, as this could be done in one simple shipment rather than organizing a lot of advanced operation involving disassemble and remanufacturing.[307] This depends on the reliability of the supply and equal importance goes to the comparable cost advantage of setting up effective post-usage loops with business partners, versus producing new components and using pure materials.[308]

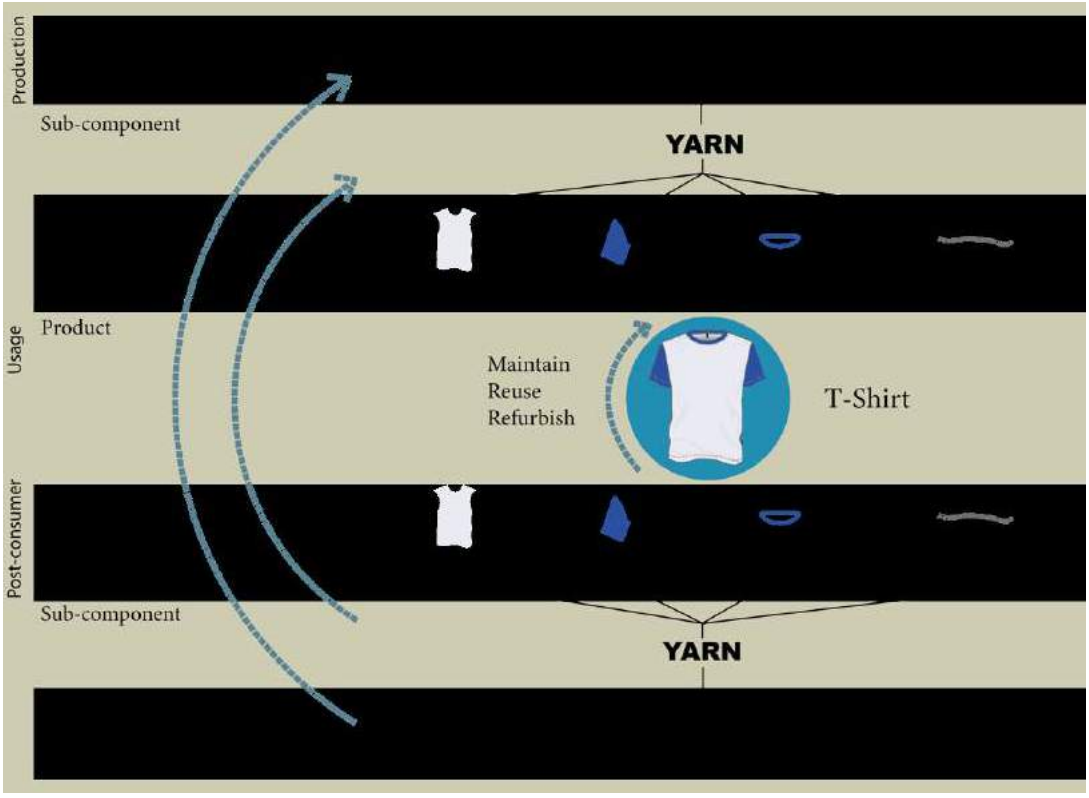

Figure 15: Utilization of reverse logistics as forwarding logistics, T-Shirt example (Source: Adapted from Ellen Macarthur Foundation, 2014)

[306] Ibid., 10.
[307] Ibid., 11.
[308] Ibid., 1.

6.9. Eco-Industrial Parks

An eco-industrial park is a common ground or land where various companies are situated in which, through unifying industrial activities, businesses seek to gain improved and efficient economic, social and environmental performance; this is also known as industrial symbiosis, which is a way of helping businesses to achieve competitive advantage by sharing or trading resources like energy, water, and by-products from manufacturing process for the sustainable growth eventually.[309] These parks can be identified by distinctive names including industrial zones, special economic zones and industrial corridors; all of which have the same purpose like performing industrial activities.[310] Table 11 below shows combination of commonly used terminologies that are related to the practice of eco-industrial parks.

ECO		**INDUSTRIAL**		**PARK**
SUSTAIBABLE	<	(SPECIAL) ECONOMIC	>	ZONE
LOW CARBON		TECHNOLOGICAL		AREA
GREEN		INVESTMENT		CLUSTER
CIRCULAR		MANUFACTURING		ESTATE

Table 11: Universally used combinations of Terminologies in relations to Eco-Industrial Parks (Source: UNIDO, WBG & GIZ, 2017)

In the modern manufacturing landscape, eco-industrial parks can play a key role, especially with respect to improving the efficiency of resources and reducing the negative environmental effects of industrial production.[311] The idea of circular economy on the other hand relates to an industrial economy having a zero-waste approach for our resource-constrained world. That is why the realization of eco-industrial parks can be treated as a tool to implement the circular economy at the industrial level.[312] Furthermore, within this industrial park, waste generated from one unit or industry can be a resource for another unit which can ensure “zero-waste”, closing cycles, and eventually maintain the circularity.[313] As an industry

[309] Cf. Online: United Nations Industrial Development Organization- UNIDO (2019)
[310] Cf. Online: UNIDO, WBG, & GIZ (2017)
[311] Cf. Online: EU (2014)
[312] Cf. Online: Cavallo & Cencioni (2017)
[313] Cf. Online: Ranta & Saari (2019)

collaboration platform, eco-industrial park can also be of huge support to overcome challenges like lack of information and high transaction costs and most importantly, companies can find collaborative partners.[314]

The hypothesis of Eco-industrial parks has been first introduced in 1992, Rio de Janeiro at the United Nations Conference on Environment and Development (UNCED) to reunite economic performance and environmental sustainability.[315] The prototype of industrial symbiosis network was first introduced in Kalundborg, Denmark by establishing "Kalundborg Eco-Industrial Park" where companies can cooperate to use or share the by-products or services of each other.[316] As an example, below figure 16 illustrates the material sharing flow among different plants in Kalundborg eco-industrial park.

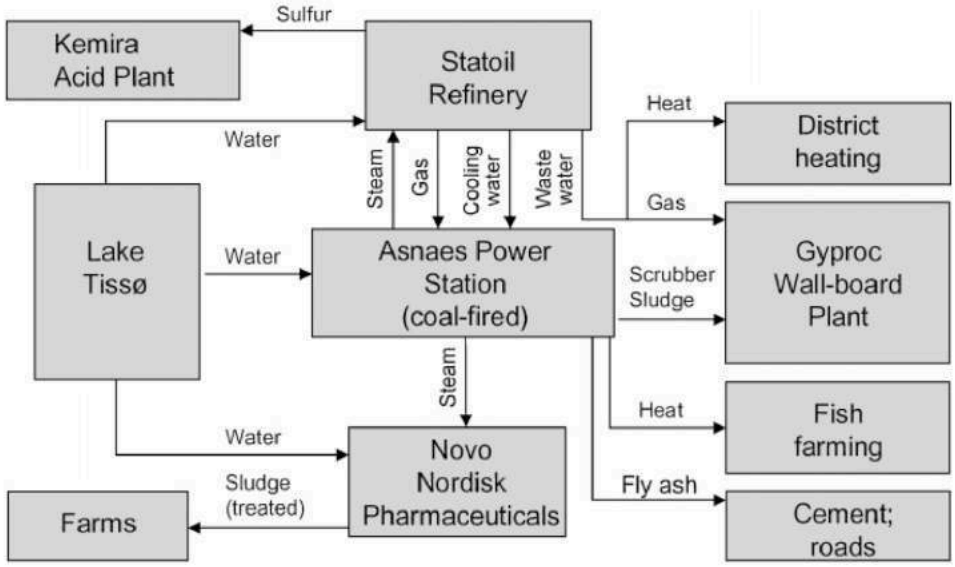

Figure 16: Material sharing flowchart in the Kalundborg Eco-Industrial Park (Source: Marian R. Chertow, 2000)

There are many other eco-industrial parks which can be found all over the world. There are Rotterdam Harbor based in the Netherland, Pomacle-Bazancourt Park from eastern France, the Deux Synthe Park from northern France, and so on.[317] To gain a steady foothold in the international textiles and garment export markets

[314] Cf. Online: Ellen MacArthur Foundation (2015)
[315] Cf. Online: UNCED (1992)
[316] Cf. Online: Marian R. Chertow (2000)
[317] Cf. Online: Planete-energies (2016)

Ethiopia has set up “Hawassa Industrial Park” in Hawassa city, southeast of Addis Ababa with Zero Liquid Discharge (ZLD) facilities.[318] There is Tianjin Park from Beijing, China comprised of 14,000 various companies like automobile, information technology, food, and petrochemical industries.[319]

China promoted the circular economy at the beginning of 2002.[320] The State Environmental Protection Administration (SEPA) of China approved the establishment of the first national eco-industry demo park in Nanhai which includes industries such as textiles, construction, ceramics, and electrical equipment to overcome the environmental challenges of the recycling and green economy.[321] Furthermore, China prepared a leading action plan where they proposed two approaches to accelerate circular economy transformation. The first way is about reshaping whole value chain by stimulating eco-design, green and renewable resource consumption, as well as developing raw material formation. The other one is about developing industrial system with the help of circular production, industrial parks development for circularity and circulation among industries in the park. Besides that, the state council of China put a work plan into effect to establish “waste-free-cities”. These promising steps will accelerate the circular economy in China. Following figure 17 is a circular economy development model developed by china to see how multiple industries can work in an eco-industrial park.[322]

[318] Cf. Online: Ethioembassy (2016)
[319] Cf. Online: TEDA (n.d)
[320] Cf. Online: R.Rathinamoorthy (2019)
[321] Cf. Online: Lin et al. (2004)
[322] Ibid., 55.

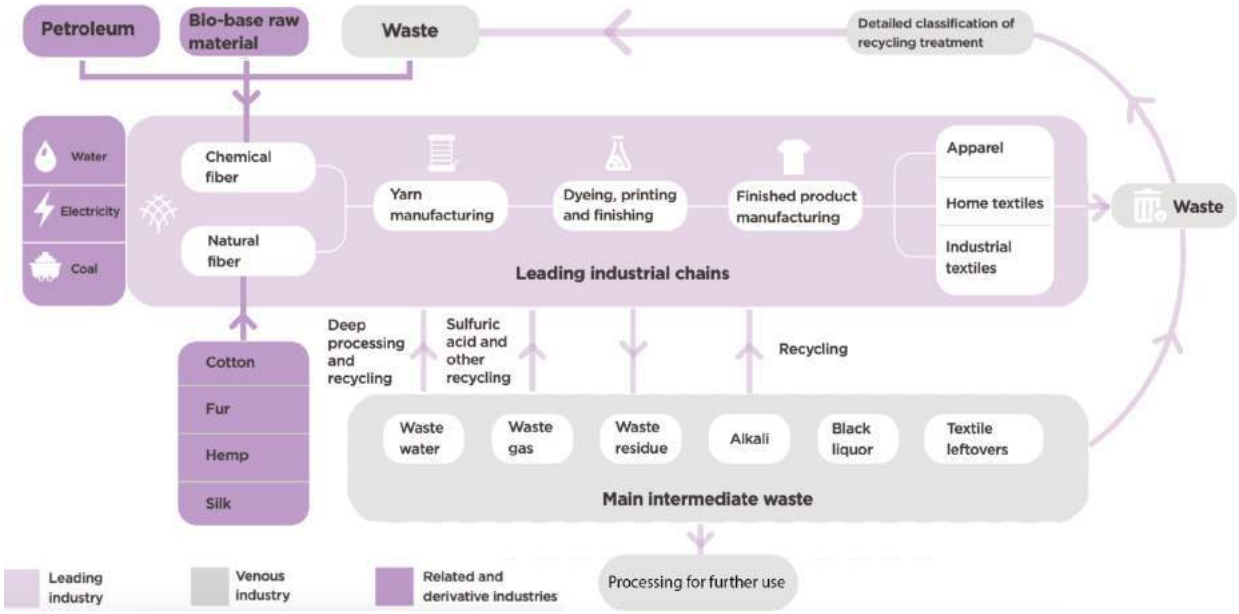

Figure 17: Circular economy basic development model for textile industry in China (Source: The State Council of the People's Republic of China as cited in CNTAC, Ellen MacArthur Foundation & Lenzing, 2020)

Circular economy plans have been able to link the development of eco-industry with cleaner production strategies for the implementation of a circular economy in certain regions in China and this shows that the eco-industrial parks are linked to the success of a circular economy.[323]

6.10. Investment for innovations and infrastructures

As one of the key success factors, the circular economy needs significant investments in a number of fields, from funding start-ups working with innovative circularity concepts to developing large-scale recycling and waste management infrastructure. It is very much clear that, we must invest in research, infrastructures, and developing technologies which will allow consumers to make safer choices. But the investment in new infrastructure is crucial in transitioning to a circular economy and currently the funding that will serve as a foundation to shift to new circular business models noticeably surpass what is preferably available.[324] For example, by 2050, an estimated $3.5 trillion valuation of investments are necessary to maintain global warming by developing "Clean energy

[323] Cf. Online: El-Haggar (2007)
[324] Cf. Online: Lacy, Long, & Spindler (2020)

infrastructure"[325] A body of United Nations, UNCTAD projected on an average $3.9 trillion of investment is required annually until 2030 to reach the "17 Sustainable Development Goals" exclusively for developing countries; it also showed that only public investment projects account for 36% of this investment leaving a gap of $2.5 trillion as shown in below figure 18.[326]

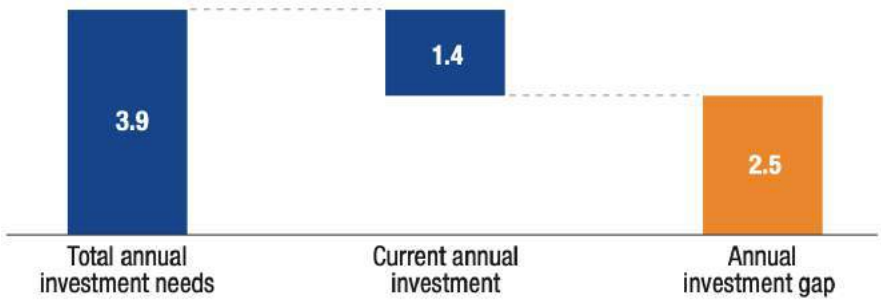

Figure 18: Projected yearly demands for investment in developing countries
(Source: United Nations Conference On Trade and Development - UNCTAD, 2018)

It can also be noticed that private-sector's funds are getting increased these days; The number of private sector funds with a focus on the circular economy has risen 10 times from 2016 till the beginning of 2020,[327] which is illustrated in figure 19 below.

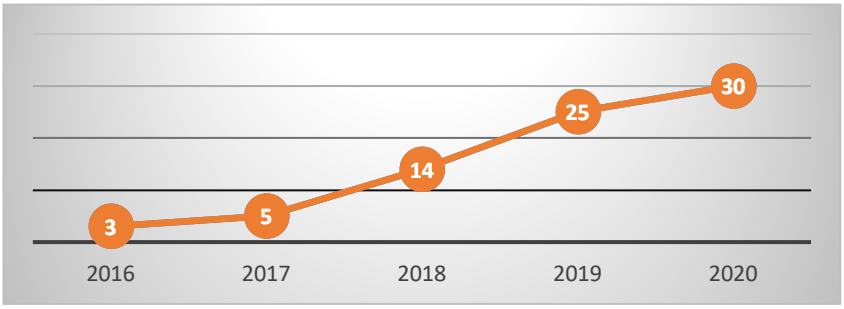

Figure 19: Number of private market funds from 2016 to 2020
(Source: Ellen MacArthur Foundation, 2020)

The global market for green chemistry is predicted to hit US$167.1 billion by the year 2027 according to ReportLinker,[328] which will be creating more prominent

[325] Cf. Online: Freke (2019)
[326] Cf. Online: United Nations Conference On Trade and Development - UNCTAD (2018)
[327] Cf. Online: Ellen MacArthur Foundation (2020)
[328] Cf. Online: ReportLinker (2020)

ways for chemical suppliers to cash in on their internal circularity. Therefore, they should need and initial investment to obtain green chemistry principles such as waste prevention, energy efficiency growth, renewable feedstocks use, and so on. These adoptions have a good chance to be offset because sustainable products increase demand.[329] Additionally, according to Accenture, the circular economy may contribute to an additional $4.5 trillion economic value by 2030 out of worldwide business,[330] and that also needs accessible investment. Different kinds of finance providers are available in the market to provide access to these investments in order to create innovative clothing and enable businesses to take circular measures which are described below.[331]

6.10.1. Banks or lenders

Banks and other lending institutions can contribute to the transformation towards a circular economy by providing credit instruments. “Sustainability-linked loans” (SLLs) have been introduced with low-interest rates to finance the business who are maintaining the sustainability key performance indicators (KPI).[332] As one of the first companies, PRADA signed a 5-year “sustainability-linked loan” with Crédit Agricole Group for €50 million and their interest rates for this loan will be adapted yearly based on the status of meeting sustainability targets.[333]

6.10.2. Commercial investors

Commercial investment sometimes can have long-term investment range comprised of specialist growth, private and project equity finance firm with having a focus on developing circular economy infrastructure.[334] Furthermore, infrastructure investors require technical knowledge like chemical recycling of clothing waste which in many cases they lack including the understanding of the circular business models; these characteristics are really important to have to provide financial support.[335] An example would be “Closed Loop Partners”, a firm

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[329] Ibid., 47.
[330] Cf. Online: Accenture (2015)
[331] Ibid., 75.
[332] Cf. Online: BNP Paribas (2019)
[333] Cf. Online: Biondi (2019)
[334] Ibid., 75.
[335] Cf. Online: Ley et al. (2020)

who focuses on the development of circular economy. They financed 'Evrnu' a textile company for innovations who focuses on fibre technologies made from thrown away clothing.[336]

6.10.3. Non-commercial finance providers

There are institutions or entities whose investments or financial support are not mostly intended for commercial advantage and their contribution to the circular economy may contribute to creating necessary infrastructures. European Investment Bank (EIB), one of the most significant multilateral lenders of green finance contributed €2.5 billion to co-finance the circular economy projects in different sectors and initiated a collaborative effort of €10 billion to facilitate the transition into circular economy.[337] "European Investment Bank" funded for "polyester staple fibre" (PSF) production facility from polyethylene terephthalate (PET) bottles and expansion of existing waste recycling infrastructure in a project called "Green Group" in Romania.[338]

6.10.4. Corporate venturing

Corporate venturing involves setting strategic collaborations with external ventures like start-ups or scaleup companies from outside the organization[339] where the organization invests the corporate funds and supports to achieve mutual growth.[340] In 2015, the "H&M Foundation" a non-profit organization launched the "Global Change Award" program to accelerate the method of innovations and recycling strategies which can help making the whole fashion industry circular.[341] Also, H&M together with other service-providing companies like RGE Pte Ltd from Singapore, 'Virala' from India and 'Fortum' from Finland invested and provided support to a Finland based sustainable fibre manufacturing company called "Infinited Fibre Company" to scale up its fibre manufacturing technologies.[342] 'Patagonia' invested

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[336] Cf. Online: Closed Loop Partners (2019)
[337] Cf. Online: European Investment Bank (2020)
[338] Cf. Online: European Investment Bank (2017)
[339] Cf. Online: Peteghem; Mohout (2018)
[340] Cf. Online: Chesbrough (2002)
[341] Cf. Online: Global Change Award (n.d)
[342] Cf. Online: Infinitedfiber (2019)

in “Mango Materials” a renewable bioproducts company to produce biodegradable material from waste that is a substitute for polyester.[343]

6.11. More innovations and initiatives driving circular economy

A full-scale formation of a circular economy can be facilitated by continuous innovations and initiatives that will also make sure to get a closed-loop system, reduce waste and carbon footprint.[344] A closed-loop system is assumed to be achievable through repair, recycling, reuse, maintenance, and a more durable design. Hong Kong Research Institute of Textiles & Apparel (HKRITA), introduced an award-winning project called hydrothermal system focusing on closing the loop which can process blended materials like cotton-polyester composition and separate them into fibres.[345]

Previously it was impractical to recycle clothing made of cotton technically, but Fraunhofer Institute for Applied Polymer Research (IAP) has been successful to create a viscose fibre from recycled cotton; the end fibre consists of pure cellulose which makes it eco-friendly as well as this fibre fits for large-scale production.[346] There could be one option to give a product a new life by buying a vintage clothing, but in the long run, clothing has a limited lifespan, since they are often thrown away at the end of their life cycle.[347] The circular economy operation includes the proper use of the product to lengthen the life cycle. And by prolonging the life cycle of the product with the help of designing, repairing, and remanufacturing, the product value can be maintained.[348] Smart clothing also ought to be treated as an innovation for circular economy transition, because it may encourage the customer to expand their clothing utility and to propose a new lifestyle. And to bring that encouragement, there could be some kind of attachment between the customer and product by bringing some functionality in the product. Most people tend to keep certain items longer if they have a stronger bonding to

[343] Cf. Online: Patagonia (2018)
[344] Cf. Online: European Institute of Innovation and Technology-EIT (2020)
[345] Cf. Online: Hong Kong Research Institute of Textiles and Apparel – HKRITA (n.d)
[346] Cf. Online: Fraunhofer (2020)
[347] Cf. Online: Chemistrycan (n.d)
[348] Cf. Online: Accenture (2014)

those items.[349] Likewise, increasing the utilization of smart clothing, it is fundamental to make personal bonds along with technical means to expand the products' actual utilization cycle. Multifunctional fibre materials designed with a special coating, to meet the specific requirement through custom-made properties is of great interest as technical means. When this smart coating is in accordance with the future economic model "made to be made again" or "designed for circular economy", they ended up of endless industrial significance.[350] Furthermore, when innovative fibres are introduced to increase garment usefulness, it also needs to be ensured that this does not diminish recyclability. An innovation called nanotechnology within clothing business is not a brand-new wonder. Some clothing companies started working with silver nanoparticles in their products.

Especially, the inferior properties of cotton fibres and yarns can be upgraded by engineering the physical, chemical, and surface, to create the desired properties, for instance, softness, durability, and breathability.[351] And this nano-infused product range could extend from socks to T-shirts.[352] If a T-shirt is considered with these smart functions, the T-shirt can have stain-resistant coating which will reduce the number of washes needed throughout its whole life. These technologies are still at the development stage, however, expect to bring changes in the customer behavior of using cloths. Furthermore, smart clothing would allow sorting machines to identify fibre types and decide the next steps for processing with no significant loss in fibre quality.[353]

In May 2017, at Copenhagen Fashion Summit, 64 leading fashion brands signed a commitment to accelerate the transition of circular fashion system in the world's economy.[354] As a sustainability effort with the motto '#wearthechange', C&A introduced worldwide first gold level "Cradle to Cradle" certified T-shirts which are of 100% organic cotton with 100% non-toxic chemicals.[355]

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[349] Cf. Online: BUSE & TWIGG (2016)
[350] Cf. Online: Tukker (2015)
[351] Cf. Online: Sawhney et al. (2010)
[352] Cf. Online: Soutter (2012)
[353] Ibid., 1.
[354] Cf. Online: Global fashion agenda (2018)
[355] Ibid., 37.

H&M in partnership with Ellen MacArthur Foundation is driving the transition to a circular economy in their business models by producing cloths from more renewable sources as well as arranges campaigns that bring brands, suppliers, and government representatives together.[356]

Concentrating on recycled cotton, polyester, and wool, Inditex triggered new ways of research in collaboration with the Massachusetts Institute of Technology (MIT) to improve the way of recycling the fibres and they also developed Refibra™Lyocell fibre from cotton clothing waste in partnership with Lenzing, an Austrian company.[357]

The Italian luxury fashion brand, 'PRADA' proclaimed that it will stop using fur in its products and after a month, the band launched a line of six bags made with "Econyl regenerated yarn" which is made from recycled plastic and clothing fibre waste.[358]

A tech-based company, 'Teemill' has developed a circular production operation that converts a used T-shirt as a newborn T-shirt by using new technology across whole life cycle of the product.[359] They also make sure to use environmentally friendly and most importantly plastic-free materials in their T-shirts as well as in all the packaging.[360]

Fashion companies are working in educating the customers to take care for their products to make them survive longer while decreasing the environmental collision throughout the use stage. 21% of climate impacts due to clothing occur once the product left the store and during the use phase, therefore, H&M is providing eco-friendly detergents, sewing kits, deco-patches, innovative washing bags, and care advice to the customer to prolong their cloths.[361] Nudie Jeans is offering free repair service in their repair store and sell repair kits as a contribution to further stretch

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[356] Cf. Online: HM group (n.d)
[357] Cf. Online: Inditex (2016)
[358] Ibid., 77.
[359] Cf. Online: Ellen Macarthur Foundation (2019)
[360] Cf. Online: Spring wise (2020)
[361] Cf. Online: H&M (2018)

their products' life cycle.[362] Another solution introduced by 'DUPONT' is an integrated safeguarding system against colour loss, odor, and fibre degradation to help the fabric of a product smell fresh and stay clean which ultimately encourages customers to use their product longer.[363]

As an attempt to take control of plastic packaging waste, Nike launched the polybag collection program called "Bag to Better" at their distribution centers from where they give the used polybags to a plastic recycler who recycles them into shopping bags.[364] 'Patagonia' is also doing the same, moreover, they collect plastic mailers from their customers through postal service or retails stores.[365]

As a supportive solution for both environment and business, the government can offer incentives like reducing 'VAT' or 'Tax' for services which intends to prolong a product's life, for example, services like specialized washing and repairing.[366]

6.12. Efforts on consumer awareness

Customer perception of fashion is usually more prevalent than the concerns for the environment. That is why their environmental or moral concerns do not all the time reflect in their buying behaviour.[367] Their purchasing decisions are sometimes unjustifiable and not always well associated with their values,[368]. And, since consumer habits are fundamental and ultimately, they decide how to dispose of their garments, therefore, this should be a prerequisite to strengthening the knowledge of consumers on sustainable value chains through putting efforts like doing campaigns on consumer awareness to support circular transformation. In a similar case, the Waste and Resources Action Programme (WRAP) from UK is working collaboratively for campaign implementation. WRAP as a work of the "Sustainable Clothing Action Plan (SCAP) introduced a consumer campaign called "Love Your Clothes" which is investigating consumer states of mind to the

[362] Cf. Online: Nudiejeans (n.d)
[363] Cf. Online: DUPONT (n.d)
[364] Cf. Online: Nike (n.d)
[365] Cf. Online: Cohen (n.d)
[366] Cf. Online: Bluff (2016)
[367] Cf. Online: Connell (2011)
[368] Cf. Online: Niinimäki (2010)

products and influencing them to avail more sustainable viewpoint in order to reduce the impact of clothing on the environment.[369] Besides this, WRAP also does “consumer clothing survey” every year about their buying behaviour, use and the way they toss out their cloths.[370]

Furthermore, to transform purchasing intentions into changed purchasing practices, clothing brands can emphasize consumers to set individual targets by goal-setting campaigns.[371] For example, a charitable organization ‘Oxfam’ launched a campaign termed “Second hand September” for the consumer to take a pledge to “shop only second hand for 30 days or more” which will allow cloths a longer life including contributing to poverty by charity work.[372]

7. Summary

Giorgio Armani, an Italian fashion designer, once said, “I have always thought of the T-shirt as the Alpha and Omega of the fashion alphabet”. No matter what outfit one wears it with, jeans, shorts, or even a skirt, it is never going to go wrong. It is also possible to create an entire outfit based on a simple tee.[373] In 2019, this everyone’s must-have clothing item totaled US$47.3 billion in global sales, where specifically the value of cotton T-shirt accounted for around 68% of the overall exported T-shirts.[374] But it has been made perceptible that, current linear product design on this huge demand of T-shirts has poor chances of reaching sustainable development for the future. Necessarily, the circular economy system got more consideration and is evolving which should make the circulation and cascading of product and materials at most of its value for the longest time.

It should be possible to produce a T-shirt, designing with 100% organic cotton fibre, grown based on regenerative farming method with safe materials like non-toxic dyes and chemicals with the help of innovative dyeing technologies.

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[369] Cf. Online: WRAP (2017)
[370] Ibid.
[371] Cf. Online: Haigh, Lembachar, & Gardien (2020)
[372] Cf. Online: Oxfamapps (2020)
[373] Cf. Online: Castro (2014)
[374] Cf. Online: Wokrman (2020)

Eventually, the end product could be a fully compostable t-shirt after the customer is done using it, which will lead to reduced environmental impact. But if we truly want to embrace the circular economy, we will have to get out of this throwing-out mentality. Same principle applies to T-shirt with other cellulose, bio-based and synthetic fibres. Apart from proper chemical management and reducing the use of water and energy leakage, there must be the focus on designing a T-shirt with inputs that are safe and renewable in order to achieve longevity and cyclability so that, eventually, it can be reused and recycled too. In terms of reusing, if the clothing brands can make their T-shirts' durability more attractive to customers, the customer will use this T-shirt as long as it can serve the purpose. And, when the T-shirt can no longer be worn, it should be returned to the right channels so that, it can be resold or reused further and recycled safely. Now, the issue is, after a long-term use, a simple T-shirt could be too dingy and shabby to resale or even to donate without any recovery treatment for further use. But that does not mean it will have to end up in the landfill. From the viewpoint of recycling, a material recovery approach must be applied. Clothing industry should be able to upcycle or at least, downcycle this T-shirt such as making another T-shirt by achieving original value or use the recycled material to produce another garment with maintaining appealing and financial value for the market. Currently, practices like innovative and high-quality recycling of clothing are still in limited scope, which needs more investment in technologies and infrastructures development. In the meantime, if clothing industry adheres to producing T-shirts with as few pure materials as possible, it would be easier to close the loop by recycling the T-shirt in a reverse network, for example, in terms of fibre, keeping it in 100% cellulose or synthetic fibre based. Because adding blended and varieties of materials may make the recycling process more complex with current technologies,[375] which might lead to again more energy loss and waste generation. Furthermore, the main goal should be making a t-shirt circular besides making it sustainable which will lead to more reduction of environmental impact of clothing industry. Responsible chemical management can also contribute to this impact reduction. Likewise, it is important that plastic packaging that is not returnable to nature need to be taken at a cycle which does not produce waste or release to nature. Thus,

[375] Cf. Online: Earley (2016)

maintaining natural capital by managing limited resources, maximizing resource return by distributing materials with their highest value and dealing with negative value from the product and material design could all contribute to achieving circular economy. Furthermore, circular economy is not only for materials, but should be sustained for the whole system with the help of continuous economically viable innovations and cooperation of every stakeholder in the entire supply chain.

There is still a tricky issue for companies, which is to offer customers with a fair price range on a product that follows the principle of circular economy. Even though some companies are adopting this concept, some are still struggling to find this concept profitable for their business. At the same time, due to the lack of compelling regulations to impose this practice, companies still have the freedom to decide whether to be sustainable or not. However, it should also be noted, that there is a strong potential for sustainability to increase demand.[376] A survey conducted by McKinsey found that social and environmental sustainability are getting important to customers and will be a significant factor in their purchasing decision by 2025.[377] Because of this transformation of customers' taste to extra durable and recyclable product, more and more companies are realizing the advantage of circular economy model and have already begun working to create more value in the product, looking for new market opportunities and reducing the material costs.[378]

8. Conclusion

In the circular economy, dealing with waste is no longer an option; reuse and recovery of raw materials should be prime choices. These concepts have clearly appeared in the clothing industry but for certain niche markets.[379] As it also can be noticed that the number of sustainable product consumers is increasing which still appears in a niche market. Additionally, as cloths from circularity practice tend to be costly, the market for those products is also treated as a niche market. At

[376] Ibid., 47.
[377] Cf. Online: McKinsey & Company (2019)
[378] Cf. Online: Ellen MacArthur Foundation, PA Consulting Group, & Walmart (2018)
[379] Ibid., 32.

present, it might also be challenging to move forward with the circular economy concept toward mass-market even with the smart and innovative solutions for sustainability. Nevertheless, still, the entire textile industry would have to go a long way in transitioning to circular economy unless it changes the way of operating business activities. As Albert Einstein put it “We cannot solve our problems with the same thinking we used when we created them”; therefore, in the world of increased competition with the perception of more design, more production, and more sales, the circular economy could be our best chance to achieve global sustainability if we can rethink and then redesign the way we produce.

9. Future research

Post-consumer textiles, which are not recyclable, are one of the primary sources of waste. Future research could be needed on product designing to find ways to reintegrate those waste into the product, at the same time, more research is needed on sustainable alternatives for harmful chemicals which are being used in the product manufacturing stages. In addition, further studies may also be performed to extend the clothing lifetime in order to generate much use of the clothing.

10. Bibliography

Aakko, M. & Koskennurmi-Sivonen, R., 2013. Designing Sustainable Fashion: Possibilities and Challenges. [Online] Available at: https://scholar.google.de/scholar?q=Designing+Sustainable+Fashion:+Possibilities+and+Challenges&hl=en&as_sdt=0&as_vis=1&oi=scholart [Accessed 10 2020].

Abate, M. T. et al., 2020. Supercritical CO2 dyeing of polyester fabric with photochromic dyes to fabricate UV sensing smart textiles, Dyes and Pigments, Volume 183. [Online] Available at: https://doi.org/10.1016/j.dyepig.2020.108671 [Accessed 02 2021].

Accenture, 2014. Circular Advantage - Innovative Business Models and Technologies to create value in a World without limits to growth. [Online] Available at: https://www.accenture.com/t20150523T053139_w_/us-en/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Strategy_6/Accenture-Circular-Advantage-Innovative-Business-Models-Technologies-Value-Growth.pdf [Accessed 11 2020].

Accenture, 2015. The Circular Economy Could Unlock $4.5 trillion of Economic Growth. [Online] Available at: https://newsroom.accenture.com/news/the-circular-economy-could-unlock-4-5-trillion-of-economic-growth-finds-new-book-by-accenture.htm [Accessed 12 2020].

Accenture, 2019. CHEMICAL (RE)ACTION. [Online] Available at: https://www.accenture.com/_acnmedia/PDF-107/Accenture-Chemicals-Circular-Economy-Growth.pdf [Accessed 02 2021].

Acero, A. P., Rodríguez, C. & Ciroth, A., 2015. Impact assessment methods in Life Cycle Assessment and their impact categories, LCIA methods, version: 1.5.2. [Online] Available at: https://www.openlca.org/wp-content/uploads/2015/11/LCA-METHODS-v.1.5.2.pdf [Accessed 03 2021].

AFIRM Group, 2020. Apparel and Footwear International RSL Management Group, Restricted Substances List. [Online] Available at: https://www.afirm-group.com/wp-content/uploads/2020/03/2020_AFIRM_RSL_2020_0130_EN.pdf [Accessed 01 2021].

Aho, M., 2016. GAIA BLOG - DESIGNING CIRCULAR ECONOMY. [Online] Available at: https://www.gaia.fi/blog/consumer-good-services/designing-circular-economy/ [Accessed 01 2021].

Al-Salem, S., Lettieri, P. & Baeyens, J., 2009. Recycling and recovery routes of plastic solid waste (PSW): A review, Waste management, Volume 29, Issue 10, Pages 2625-2643,. [Online] Available at: https://doi.org/10.1016/j.wasman.2009.06.004 [Accessed 02 2021].

Alkaya, E., Böugürcü, M., Ulutacs, F. & Demirer, G., 2011. Cleaner (sustainable) production in textile wet processing. [Online] Available at:

https://www.researchgate.net/publication/260425300 Cleaner sustainable produc tion in textile wet processing [Accessed 01 2021].

Altstädt, P. D. V., 2008. Electrospun Polymeric Fine Fibers. [Online] Available at: https://analyticalscience.wiley.com/do/10.1002/imaging.1826 [Accessed 11 2020].

Amini, S., Remmerswaal, J., Castro, M. & Reuter, M., 2007. Quantifying the quality loss and resource efficiency of recycling by means of exergy analysis. Journal of Cleaner Production, 15(10), pp. 907-913 [Online] Available at: https://www.sciencedirect.com/science/article/abs/pii/S095965260600062X?via%3 Dihub [Accessed 01 2021].

Anna-Luisa Müller, R. P., 2014. Business transformation towards sustainability. Bus Res 7, 313–350. [Online] Available at: https://doi.org/10.1007/s40685-014-0011-y [Accessed 10 2020].

Anon., 2000. Remediation of dyes in textile effluent: a critical review on current treatment technologies with a proposed alternative, Biotechnology Research Group, School of Applied Biological and Chemical Sciences, University of Ulster, Coleraine, BT52 1SA, UK. [Online] Available at: https://www.academia.edu/1891708/Remediation of dyes in textile effluent a c ritical review on current treatment technologies with a proposed alternative [Accessed 01 2021].

Arnold Tukker, 2015. Product services for a resource-efficient and circular economy – a review. Journal of Cleaner Production, Volume 97, pp. 76-91. [Online] Available at: https://doi.org/10.1016/j.jclepro.2013.11.049 [Accessed 01 2021].

Asim, M. et al., 2015. A Review on Pineapple Leaves Fibre and Its Composites, International Journal of Polymer Science, vol. 2015, Article ID 950567, 16 pages. [Online] Available at: https://doi.org/10.1155/2015/950567 [Accessed 01 2021].

Auckland Council, 2016. How many times can it be recycled?. [Online] Available at: https://ourauckland.aucklandcouncil.govt.nz/articles/news/2016/08/how-many-times-can-it-be-recycled/ [Accessed 01 2021].

Banat, I. M., Nigam, P., Singh, D. & Marchant, R., 1996. Microbial decolorization of textile-dye-containing effluents: A review, Bioresource Technology, Elsevier Science Limited. [Online] Available at: https://doi.org/10.1016/S0960-8524(96)00113-7 [Accessed 01 2021].

Barker, T., 2018. Comparison of Carton and Plastic Packaging Sustainability, Truffula Ltd.. [Online] Available at: https://www.procarton.com/wp-content/uploads/2018/06/PC-Carton-Plastic-Sustainability.pdf [Accessed 02 2021].

Bell, K. & Cave, S., 2011. Comparison of Environmental Impact of Plastic, Paper and Cloth Bags, Northern Ireland Assembly. [Online] Available at: http://www.niassembly.gov.uk/globalassets/documents/raise/publications/2011/environment/3611.PDF [Accessed 02 2021].

Berg, G. L. M., 2020. mckinsey. [Online] Available at: https://www.mckinsey.com/industries/retail/our-insights/fashion-on-climate [Accessed 10 2020].

Brahma, S., Islam, M. R. & Salima Sultana Shimo, R. B. D., 2019. Influence of Natural and Artificial Mordants on the Dyeing Performance of Cotton Knit Fabric with Natural Dyes, IOSR Journal of Polymer and Textile Engineering (IOSR-JPTE) e-ISSN: 2348-019X, p-ISSN: 2348-0181, Volume 6, Issue 1, PP 01-06. [Online] Available at: https://www.researchgate.net/publication/330502592 Influence of Natural and A rtificial Mordants on the Dyeing Performance of Cotton Knit Fabric with Nat ural Dyes [Accessed 02 2021].

BIONDI, A., 2019. Vogue Business - Prada is first in industry to sign sustainability-linked loan. [Online] Available at: https://www.voguebusiness.com/sustainability/prada-launches-sustainability-linked-loan [Accessed 12 2020].

BlockTexx, n.d. blocktexx-Unlocking the value of textile waste. [Online] Available at: https://www.blocktexx.com/ [Accessed 11 2020].

Bluff, J., 2016. Swedish Government Wants to Give People a Tax Break for Fixing Their Stuff. [Online] Available at: https://www.ifixit.com/News/8405/sweden-repair-tax [Accessed 11 2020].

BNP Paribas, 2019. SUSTAINABLE FINANCE: THE RISE AND RISE OF SUSTAINABILITY-LINKED LOANS. [Online] Available at: https://cib.bnpparibas.com/sustain/sustainable-finance-the-rise-and-rise-of-sustainability-linked-loans a-3-3008.html [Accessed 12 2020].

Botanical Colors, n.d. Logwood Extract. [Online] Available at: https://botanicalcolors.com/shop/natural-dyes/natural-dye-extracts/logwood-extract/ [Accessed 02 2021].

Boulding, K. E., 1966. The Economics of the Coming Spaceship Earth, H. Jarrett (Ed.), Environmental Quality Issues in a Growing Economy, Johns Hopkins University Press (1966), pp. 3-14. [Online] Available at: http://arachnid.biosci.utexas.edu/courses/THOC/Readings/Boulding SpaceshipEa rth.pdf [Accessed 01 2021].

Briggs, F., 2020. UK consumers lagging behind Italy, Spain and Germany when it comes to awareness of sustainability in fashion. [Online] Available at: https://www.retailtimes.co.uk/uk-consumers-lagging-behind-italy-spain-and-germany-when-it-comes-to-awareness-of-sustainability-in-fashion/ [Accessed 10 2020].

Brigden, K. et al., 2013. Hazardous chemicals in branded textile products on sale in 25 countries/regions during 2013, Greenpeace Research Laboratories. [Online] Available at: https://www.greenpeace.org/static/planet4-thailand-stateless-release/2019/09/192afd2f-a-little-story-about-the-monsters-in-your-closet-technical-report.pdf [Accessed 02 2021].

Brown & Wilmanns Environmental (bwe), n.d. Industry partnership, non-profit and non-governmental organizations, Environmental Benchmark for Fibres. [Online] Available at: https://www.bw-environmental.com/industry-org-ngo-non-profit [Accessed 02 2021].

C&A, 2018. Global Sustainability Report 2018. [Online] Available at: https://sustainability.c-and-a.com/uk/en/sustainability-report/2018/suppliers-list/ [Accessed 10 2020].

Cadel Deinking, n.d. The Deinking Process. [Online] Available at: http://cadeldeinking.com/en/# process [Accessed 02 2021].

Caputo, L., 2016. PRANA BECOMES A POLYBAG HERO. [Online] Available at: https://outdoorindustry.org/article/prana-becomes-a-polybag-hero/ [Accessed 02 2021].

Cargo Handbook, n.d. Diisononylphthalate (DNP), BMT. [Online] Available at: https://cargohandbook.com/Diisononylphthalate (DNP) [Accessed 02 2021].

Castro, E. J., 2014. A cut above the rest. [Online] Available at: https://cebudailynews.inquirer.net/17080/a-cut-above-the-rest [Accessed 02 2021].

Cavallo, M. & Cencioni, D., 2017. CIRCULAR ECONOMY, BENEFITS AND GOOD PRACTICES, Publisher: Edizioni Ambiente srl. [Online] Available at: https://www.researchgate.net/publication/326106729 Circular Economy benefits and good practices [Accessed 12 2020].

Centers for disease control and prevention (CDC), n.d. Glossary of volatile organic compounds. [Online] Available at: https://www.cdc.gov/nceh/clusters/fallon/glossary-voc.pdf [Accessed 02 2021].

Chalmin, P., n.d. The history of plastics: from the Capitol to the Tarpeian Rock, Field Actions Science Reports, Special Issue 19 | 2019, 6-11. [Online] Available at: http://journals.openedition.org/factsreports/5071 [Accessed 01 2021].

Chapagain, A., Hoekstra, A., Savenije, H. & Gautam, R., 2005. The water footprint of cotton consumption, s.l.: UNESCO-IHE. [Online] Available at: https://www.researchgate.net/publication/228377230 The Water Footprint of Co tton Consumption [Accessed 10 2020].

Chemistrycan, n.d. Extending the lifecycle of garments and textiles. [Online] Available at: https://chemistrycan.com/case-study/re-purposing-textile-from-start-to-finish/ [Accessed 11 2020].

Chen, H.-L. & Burns, L. D., 2006. Environmental Analysis of Textile Products. Issue 3, pp. 248-261. [Online] Available at: https://doi.org/10.1177/0887302X06293065 [Accessed 11 2020].

Chem-MAP®, Eurofins, 2018. MRSL and RSL – What is the Difference?. [Online] Available at: https://www.chem-map.com/chemical news/mrsl-and-rsl-what-is-the-difference/ [Accessed 02 2021].

Chesbrough, H., 2002. Harvard Business Review - Making Sense of Corporate Venture Capital. [Online] Available at: https://hbswk.hbs.edu/archive/making-sense-of-corporate-venture-capital [Accessed 12 2020].

Circle Economy, 2020. Circularity-Gap; The Circularity Gap Report 2020. [Online] Available at: https://www.circularity-gap.world/2020 [Accessed 11 2020].

Circular design guide, n.d. Material Selection - Choose the right materials for your new circular design. [Online] Available at: https://www.circulardesignguide.com/post/material-selection [Accessed 11 2020].

Clay, J., 2004. World Agriculture and the Environment: A Commodity-By-Commodity Guide To Impacts And Practices. s.l.:Island Press; 4th ed edition (31 Oct. 2003). [Online] Available at: https://www.researchgate.net/publication/37717451 World Agriculture and the Environment A Commodity-By-Commodity Guide To Impacts And Practices [Accessed 11 2020].

Climate-kic, n.d. EIT Climate-KIC. [Online] Available at: https://www.climate-kic.org/innovation-spotlight/ioncells-fiber-innovation-could-drive-circular-economy/ [Accessed 10 2020].

Closed Loop Partners, 2019. Building the Circular Economy-Closed Loop Partners impact Report, s.l.: s.n. [Online] Available at: https://www.closedlooppartners.com/wp-content/uploads/2020/02/Closed-Loop-Partners-2019-Impact-Report-1.pdf [Accessed 12 2020].

Connell, K. Y. H., 2011. Exploring consumers' perceptions of eco-conscious apparel acquisition behaviors. [Online] Available at: https://www.researchgate.net/publication/227430338 Exploring consumers%27 p erceptions of eco-conscious apparel acquisition behaviors [Accessed 11 2020].

Cotton made in Africa, n.d. cottonmadeinafrica. [Online] Available at: https://cottonmadeinafrica.org/en/about-us/ [Accessed 11 2020].

Cottonworks, n.d. What is Cationic Cotton?. [Online] Available at: https://www.cottonworks.com/topics/sourcing-manufacturing/dyeing/cationic-cotton/# [Accessed 02 2021].

Cucchiella, F., D'Adamo, I., Koh, S. L. & Rosa, P., 2015. Recycling of WEEEs: An economic assessment of present and future e-waste streams. [Online]Available at: https://www.sciencedirect.com/science/article/abs/pii/S1364032115005808?via%3 Dihub [Accessed 10 2020].

Dahlboa, H., Aaltob, K., Eskelinena, H. & Salmenperä, H., 2017. Increasing textile circulation—Consequences and requirements (Sustainable Production and Consumption). [Online] Available at: https://www.sciencedirect.com/science/article/abs/pii/S2352550916300100 [Accessed 01 2021].

Design for longevity, n.d. Design-Longevity. [Online] Available at: https://designforlongevity.com/ [Accessed 11 2020].

Dieckmann, E. et al., 2020. Analysis of Barriers to Transitioning from a Linear to a Circular Economy for End of Life Materials: A Case Study for Waste Feathers. [Online] Available at: https://www.mdpi.com/2071-1050/12/5/1725/htm [Accessed 12 2020].

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, 2009. Selection and safe use of alternatives to CTC, Textiles Stain Removal, National CTC Phase-out Plan. [Online] Available at: http://www.ctc-phaseout.com/Stain-Removal-TA.pdf [Accessed 02 2021].

DOW, n.d. ECOFAST Pure, Sustainable Textile Treatment. [Online] Available at: https://www.dow.com/en-us/brand/ecofast.html [Accessed 02 2021].

DR. PETRY, n.d. New Range of Pigments: Garment Dyeing with Natural Pigments, News. [Online] Available at: https://drpetry.de/en/textile-news/new-range-of-pigments-garment-dyeing-with-natural-pigments.html [Accessed 02 2021].

DUPONT, n.d. Nutrition & Biosciences. [Online] Available at: https://www.dupontnutritionandbiosciences.com/silvadur/unmatched-antimicrobial-protection.html [Accessed 11 2020].

Dutch Awareness, n.d. Cliff. [Online] Available at: https://dutchawearness.com/#work-circular [Accessed 10 2020].

DW, D. W. -., 2019. In a nutshell: natural vs. chemical dyes, ECO INDIA. [Online] Available at: https://www.dw.com/en/in-a-nutshell-natural-vs-chemical-dyes/av-48379052 [Accessed 02 2021].

DyeCoo, n.d. CO2 Dyeing. [Online] Available at: http://www.dyecoo.com/co2-dyeing/ [Accessed 02 2021].

DyStar Textilfarben GmbH & Co. Deutschland KG, Green river tech, 2000. German Legislation on Azo Dyes, Ecology Dystar, 2nd issue. [Online] Available at: http://www.greenrivertech.com.tw/stand-method-pdf/rohs/azo.pdf [Accessed 02 2021].

Earley, R., 2016. Closing the loop – fashion's challenge, Filippa K Circle.. [Online] Available at: http://filippakcircle.com/2016/05/21/designing-for-cyclability-2/ [Accessed 02 2021].

EC, 2008. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on Waste and Repealing Certain Directives (Text with EEA Relevance). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008L0098 [Accessed 01 2021].

European Clothing Action Plan (ECAP), 2019. Circular-Textiles-Ready-to-market-booklet.pdf. [Online] Available at: http://www.ecap.eu.com/wp-

content/uploads/2019/02/Circular-Textiles-Ready-to-market-booklet.pdf [Accessed 11 2020].

Recovery-worldwide, 2019. The limitations of textile recycling. [Online] Available at: https://www.recovery-worldwide.com/en/artikel/the-limitations-of-textile-recycling 3411757.html [Accessed 11 2020].

EIT (European Institute of Innovation and Technology), 2020. eitrawmaterials-Circular Economy and Innovation. [Online] Available at: https://eitrawmaterials.eu/circular-economy-and-innovation/ [Accessed 11 2020].

El-Haggar, S. M., 2007. Chapter 3 - Sustainable Development and Industrial Ecology. In: S. M. El-Haggar, ed. Sustainable Industrial Design and Waste Management. s.l.:Academic Press, pp. 85-124; [Online] Available at: https://www.sciencedirect.com/science/article/pii/B9780123736239500058 [Accessed: 12 2020].

Elander, M. & Ljungkvist, H., 2016. Critical aspects in design for fiber-to-fiber recycling of textiles. [Online] Available at: http://mistrafuturefashion.com/wp-content/uploads/2016/06/MFF-report-2016-1-Critical-aspects.pdf [Accessed 10 2020].

Ellen MacArthur Foundation, 2013. Towards the Circular Economy. [Online] Available at: https://www.ellenmacarthurfoundation.org/publications/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an-accelerated-transition [Accessed 10 2020].

Ellen MacArthur Foundation, 2014. Towards the circular economy. [Online] Available at: https://www.ellenmacarthurfoundation.org/publications/towards-the-circular-economy-vol-3-accelerating-the-scale-up-across-global-supply-chains [Accessed 10 2020].

Ellen MacArthur Foundation, 2015. DELIVERING THE CIRCULAR ECONOMY, A TOOLKIT FOR POLICYMAKERS. [Online] Available at: https://www.ellenmacarthurfoundation.org/assets/downloads/government/EllenMacArthurFoundation Policymakers-Toolkit.pdf [Accessed 12 2020].

Ellen MacArthur Foundation, 2015. Towards a circular economy: Business rationale for an accelerated transition. [Online] Available at: https://www.ellenmacarthurfoundation.org/assets/downloads/TCE Ellen-MacArthur-Foundation-9-Dec-2015.pdf [Accessed 10 2020].

Ellen MacArthur Foundation, 2017. A new textiles economy: Redesigning fashion's future. [Online] Available at: http://www.ellenmacarthurfoundation.org/publications [Accessed 10 2020].

Ellen MacArthur Foundation, 2017. ACHIEVING 'GROWTH WITHIN'. [Online] Available at: https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Achieving-Growth-Within-20-01-17.pdf [Accessed 11 2020].

Ellen MacArthur Foundation, 2017. THE NEW PLASTICS ECONOMY - CATALYSING ACTION. [Online] Available at: https://www.ellenmacarthurfoundation.org/assets/downloads/New-Plastics-Economy Catalysing-Action 13-1-17.pdf [Accessed 02 2021].

Ellen MacArthur Foundation, 2019. Case studies - An open access circular supply chain for fashion. [Online] Available at: https://www.ellenmacarthurfoundation.org/case-studies/an-open-access-circular-supply-chain-for-fashion [Accessed 11 2020].

Ellen MacArthur Foundation, 2020. Measuring Circular Economy Performance - How Can Circulytics Help Your Business?. [Online] Available at: https://www.youtube.com/watch?v=xOqkIbFUPwU [Accessed 02 2021].

Ellen MacArthur Foundation, n.d. Circulytics - measuring circularity. [Online] Available at: https://www.ellenmacarthurfoundation.org/resources/apply/circulytics-measuring-circularity [Accessed 02 2021].

Ellen MacArthur Foundation, n.d. What is a circular economy? A framework for an economy that is restorative and regenerative by design. [Online] Available at: https://www.ellenmacarthurfoundation.org/circular-economy/concept [Accessed 11 2020].

Ellen MacArthur Foundation, n.d. What is the circular economy? [Online] Available at: https://www.ellenmacarthurfoundation.org/circular-economy/what-is-the-circular-economy [Accessed 11 2020].

Ellen MacArthur Foundation; PA Consulting Group; Walmart, 2018. KEEPING CUSTOMER CONNECTIONS, Why customer relationships don't have to end at the point of sale – lessons from the circular economy. [Online] Available at: https://www.ellenmacarthurfoundation.org/assets/downloads/ce100/CE100 Report Retail Customer Final.pdf [Accessed 02 2021].

Eltayeb, T. K. & Zailani, S., 2009. Going Green Through Green Supply Chain Initiatives Towards Environmental Sustainability. [Online] Available at: https://www.researchgate.net/publication/285152338 Going Green through Gree n Supply Chain Initiatives Toward Environmental Sustainability [Accessed 10 2020].

Elumalai, S. et al., 2014. recovery of dye from textile effluents using phenol as an extractant, Journal of Industrial and Engineering Chemistry, Volume 20, Issue 4. [Online] Available at: https://doi.org/10.1016/j.jiec.2013.09.017. [Accessed 01 2021].

Environmental Justice Foundation in collaboration with Pesticide Action Network UK, London, UK. ISBN No. 1-904523-10-2, 2007. THE DEADLY CHEMICALS IN COTTON. [Online] Available at: http://ejf.mudbank.uk/resources/downloads/the deadly chemicals in cotton.pdf [Accessed 02 2021].

Epyllion Style Limited, Gazipur, Bangladesh, photo by Yasir Arafat, 2021. Packing photos.

Esteve-Turrillas, F. & Guardia, M. d. l., 2016. Environmental impact of Recover cotton in textile industry. Resources, Conservation and Recycling, Volume 116, pp. 107-115 [Online] Available at: https://coek.info/pdf-environmental-impact-of-recover-cotton-in-textile-industry-.html [Accessed 01 2021].

Ethical Revolution, n.d. Zest N Zeal. [Online] Available at: https://ethicalrevolution.co.uk/listing/zest-n-zeal/ [Accessed 02 2021].

EURATEX-Prospering-in-the-Circular-Economy-2020. [Online] Available at: https://euratex.eu/ [Accessed 11 2020].

European Chemicals Agency-ECHA, 2016. Newsletter-Chemicals are at the core of the circular economy and Europe's future. [Online] Available at: https://newsletter.echa.europa.eu/home/-/newsletter/entry/chemicals-are-at-the-core-of-the-circular-economy-and-europe-s-future [Accessed 01 2021].

European commission, 2014. Towards a circular economy: A zero waste programme for Europe. [Online] Available at: https://ec.europa.eu/environment/circular-economy/pdf/circular-economy-communication.pdf [Accessed 01 2021].

European Commission, 2017. Circular economy in practice - reducing textile waste. [Online] Available at: https://ec.europa.eu/easme/en/news/circular-economy-practice-reducing-textile-waste [Accessed 10 2020].

European commission, 2018. A EUROPEAN STRATEGY FOR PLASTICS IN A CIRCULAR ECONOMY, Circular Economy package. [Online] Available at: https://ec.europa.eu/environment/circular-economy/pdf/plastics-strategy-brochure.pdf [Accessed 02 2021].

European Commission, 2019. ECO-INNOVATION, Dyeing without water. [Online] Available at: https://ec.europa.eu/environment/ecoap/about-eco-innovation/experts-interviews/tintura-senza-acqua en [Accessed 02 2021].

European Commission, 2019. Sustainable Products in a Circular Economy - Towards an EU Product Policy Framework contributing to the Circular Economy. [Online] Available at: https://ec.europa.eu/environment/circular-economy/pdf/sustainable products circular economy.pdf [Accessed 11 2020].

European Commission, 2020. SUSTAINABLE CHEMICALS FOR A CIRCULAR ECONOMY, ECO-INNOVATION at the heart of European policies. [Online] Available at: https://ec.europa.eu/environment/ecoap/about-eco-innovation/policies-matters/sustainable-chemicals-circular-economy en [Accessed 01 2021].

EUROPEAN INVESTMENT BANK, 2017. EIB-ROMANIA RECYCLING AND CIRCULAR ECONOMY PROJECT. [Online] Available at: https://www.eib.org/en/projects/pipelines/all/20160908 [Accessed 12 2020].

EUROPEAN INVESTMENT BANK, 2020. Circular Economy Overview 2020, s.l.: EIB [Online] Available at: https://www.eib.org/attachments/thematic/circular economy overview 2020 en.pdf [Accessed 12 2020].

European Union, 2014. UNIDO's side session on "Eco-Industrial Parks for a Circular Economy" at Green Week 2014. [Online] Available at: https://europa.eu/capacity4dev/unido/event/unidos-side-session-eco-industrial-parks-circular-economy-green-week-2014 [Accessed 12 2020].

European Union, 2019. DyeCoo uses reclaimed CO_2 as the dyeing medium, in a closed loop process. [Online] Available at: https://circulareconomy.europa.eu/platform/en/good-practices/dyecoo-uses-reclaimed-co2-dyeing-medium-closed-loop-process [Accessed 02 2021].

European Union, 2019. Policy Hub on Circular Economy in Apparel and Footwear, European Circular Economy Stakeholder Platform. [Online] Available at: https://circulareconomy.europa.eu/platform/en/dialogue/existing-eu-platforms/policy-hub-circular-economy-apparel-and-footwear [Accessed 02 2021].

European Union, n.d. Some phthalates and their applications, Public Health. [Online] Available at: https://ec.europa.eu/health/scientific committees/opinions layman/en/phthalates-school-supplies/figtableboxes/table-2.htm [Accessed 02 2021].

ExcelPlas; Centre for Design; Nolan, 2003. The impacts of degradable plastic bags in Australia. [Online] Available at: http://ecoportus.ru/sites/default/files/Статьи%20и%20исследования/The%20impacts%20of%20degradable%20plastic%20bags%20in%20Australia.pdf [Accessed 01 2021].

Fashion for Good , 2019. Fashion for Good Launches a Pilot to Produce a Circular Polybag. [Online] Available at: https://fashionforgood.com/our news/fashion-for-good-launches-a-pilot-to-produce-a-circular-polybag/ [Accessed 01 2021].

Fashion Positive, 2020. Circular Materials Guidelines 1.0. [Online] Available at: https://textileexchange.org/wp-content/uploads/2020/08/Circular-Materials-Guidelines-v1.0-Final-08202020.pdf [Accessed 01 2021].

Fennemann, V. & Christian Hohaus, J.-P. K., 2018. MOVING IN CIRCLES: LOGISTICS AS KEY ENABLER FOR A CIRCULAR ECONOMY. [Online] Available at: https://www.iml.fraunhofer.de/content/dam/iml/de/documents/101/09 Whitepaper CE EN WEB.pdf [Accessed 11 2020].

Fletcher, K., 2008. Sustainable Fashion and Textiles: Design Journeys. s.l.:Routledge. [Online] Available at: https://books.google.de/books?id=7mtPFUzjzLYC&printsec=frontcover&dq=Sustainable+Fashion+and+Textiles:+Design+Journeys+first+edition&hl=en&sa=X&ved=2ahUKEwjA KmztZ7vAhUB3KQKHQv2ApoQ6AEwAHoECAIQAg#v=onepage&q&f=false [Accessed 11 2020].

Fraunhofer, 2020. From old jeans to new t-shirt. [Online] Available at: https://www.fraunhofer.de/en/press/research-news/2020/august/from-old-jeans-to-new-t-shirt.html [Accessed 11 2020].

Fraser, K., 2018. 5 main hazardous chemicals in clothing from China named. [Online] Available at: https://fashionunited.uk/news/business/5-main-hazardous-chemicals-in-clothing-from-china-named/2018102939678 [Accessed 02 2021].

Freke, T., 2019. How 'Transition Bonds' can help polluters turn green; Bloomberg. [Online] Available at: https://www.bloombergquint.com/business/how-transition-bonds-can-help-polluters-turn-green-quicktake [Accessed 12 2020].

Friedman, A., 2019. This New H&M-Backed Recycled Fiber Just Got $4M in Funding to Scale its Solution, Sourcing Journal. [Online] Available at: https://sourcingjournal.com/topics/raw-materials/infinited-fiber-recycled-material-165275/ [Accessed 12 2020].

GEODIS , 2018. Circular Economy and Logistics. [Online] Available at: https://geodis.com/expertise/circular-economy-and-logistics [Accessed 11 2020].

Georgakopoulou, A., 2020. Circular Economy: Sustainable colors with biotechnology and bacteria, Pantopoulos teaching project. [Online] Available at: https://innovatebiz.eu/entrepreneurship/circular-economy-sustainable-colors-with-biotechnology-and-bacteria/ [Accessed 02 2021].

Gereffi, G., n.d. International trade and industrial upgrading in the apparel commodity chain, Journal of International Economics 48 (1999) 37–70. [Online] Available at: https://www.semanticscholar.org/paper/International-trade-and-industrial-upgrading-in-the-Gereffi/e2d334a4e925045b5f6ab4200ddee241245932dd [Accessed 01 2021].

Geyer, R., 2020. Earth and Plastic, Earth 2020-An Insider’s Guide to a Rapidly Changing Planet by Philippe Tortell. Open Book Publishers.. [Online] Available at: https://doi.org/10.11647/OBP.0193 [Accessed 02 2021].

Geyer, R., Kuczenski, B., Zink, T. & Henderson, A., 2015. Common Misconceptions about Recycling, Journal of Industrial Ecology, Volume 20, Issue 5. [Online] Available at: https://doi.org/10.1111/jiec.12355 [Accessed 02 2021].

Ginsberg, A. D. et al., 2014. Synthetic Aesthetics-Investigating Synthetic Biology's Designs on Nature, The MIT Press, England. [Online] Available at: https://books.google.de/books?id=xZ4LEAAAQBAJ&pg=PA115&lpg=PA115&dq=synthetic+aesthetics+investigating+synthetic+biology%27s+designs+on+nature+take+control+of+the+entire+lifecycle&source=bl&ots=gj6IAVgUaV&sig=ACfU3U0eK0KvawiAFnnhWMxXfah5rYrZYg&hl=en&sa=X&ved=2ahUKEwjp3LqQh9juAhUL7qQKHbr6DIU4ChDoATABegQIDhAC#v=onepage&q&f=false [Accessed 02 2021].

Global Fashion Agenda, 2017. PULSE OF THE FASHION INDUSTRY. [Online] Available at: https://www.globalfashionagenda.com/publications-and-policy/pulse-of-the-industry/ [Accessed 11 2020].

Global Fashion Agenda, 2018. Leading fashion companies set target for a circular fashion future. [Online] Available at: https://www.globalfashionagenda.com/leading-fashion-companies-set-targets-for-a-circular-fashion-future/# [Accessed 11 2020].

The Council of Fashion Designers of America, GLOBAL FASHION AGENDA: CIRCULAR DESIGN TOOLBOX. [Online] Available at: https://cfda.com/resources/sustainability-resources/detail/global-fashion-agenda-circular-design-toolbox [Accessed 10 2020].

Goldberg, E., 2016. You're Probably Going To Throw Away 81 Pounds Of Clothing This Year. [Online] Available at: https://www.huffpost.com/entry/youre-likely-going-to-throw-away-81-pounds-of-clothing-this-year n 57572bc8e4b08f74f6c069d3 [Accessed 11 2020].

Gosavi, V. D. & Sharma, S., 2013. A General Review on Various Treatment Methods for Textile Wastewater, Journal of Environmental Science, Computer Science and Engineering & Technology, Vol.3.No.1, 029-039. [Online] Available at: https://www.researchgate.net/publication/259695038 A General Review on Various Treatment Methods for Textile Wastewater [Accessed 01 2021].

Goswami, P. & T. O'Haire, 2016. Developments in the use of green (biodegradable), recycled and biopolymer materials in technical nonwovens. [Online] Available at: https://www.researchgate.net/publication/303413379 Developments in the use of green biodegradable recycled and biopolymer materials in technical nonwovens [Accessed 10 2020].

Grasso, M. M., 1995. Recycled Textile Fibers: The Challenge for the Twenty-First Century. North Carolina: s.n. Motte, D. H. d. l., 2017. mistra future fashion. [Online] Available at: http://mistrafuturefashion.com/rewind-recycles-cotton-polyester/ [Accessed 10 2020].

Grevinga, T., Lurvink, M., Brinks, G. & Luiken, A., 2017. GOING ECO, GOING DUTCH, A local and closed loop textile production system. [Online] Available at: https://www.researchgate.net/publication/320307130 GOING ECO GOING DUTCH A local and closed loop textile production system [Accessed 02 2021].

Guerra-Rodríguez, S. et al., 2020. Towards the Implementation of Circular Economy in the Wastewater Sector: Challenges and Opportunities. [Online] Available at: https://doi.org/10.3390/w12051431 [Accessed 01 2021].

Gulich, B., 2006. Designing textile products that are easy to recycle, Recycling textiles, Woodhead publishing in textiles, Page 25-36. [Online] Available at: https://books.google.de/books?hl=en&lr=&id=4uVRAwAAQBAJ&oi=fnd&pg=PA25&dq=Gulich,+B.+.+Designing+textile+products+that+are+easy+to+recycle.+Saxon+Textile+Research+Institute,+Germany:+Woodhead.&ots=bvQKZMvlsQ&sig=wWvkr5-b xihd8XY vchR45jaSo&redir esc=y#v=o [Accessed 01 2021].

Gulzar, T. et al., 2019. The Impact and Prospects of Green Chemistry for Textile Technology The Textile Institute Book Series, Pages 1-20. [Online] Available at: https://doi.org/10.1016/B978-0-08-102491-1.00001-0 [Accessed 02 2021].

Gunterpauli, n.d. Gunter Pauli. [Online] Available at: https://www.gunterpauli.com/the-blue-economy.html [Accessed 11 2020].

Gupta, S. & Veerakamolmal, P., 1996. DISASSEMBLY OF PRODUCTS, Boston: 334 Snell, Engineering Center Department of Mechanical, Industrial and Manufacturing Engineering-Northeastern University. [Online] Available at: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.42.5071&rep=rep1&type=pdf [Accessed 11 2020].

Gupta, S., 2001. Inkjet printing-A revolutionary ecofriendly technique for textile printing, Indian journal of fibre & textile research, vol. 26. pp. 156-161. [Online] Available at: http://nopr.niscair.res.in/bitstream/123456789/24925/1/IJFTR%2026%281-2%29%20156-161.pdf [Accessed 01 2021].

G.M. Williams, 9.09 - Chemicals with Carcinogenic Activity in Rodent Liver, Editor(s): Charlene A. McQueen, Comprehensive Toxicology (Second Edition), Elsevier, 2010, Pages 221-250, ISBN 9780080468846, [Online] Available at: https://doi.org/10.1016/B978-0-08-046884-6.01009-5. [Accessed 02 2021].

H&M Foundation, n.d. Global Change Award. [Online] Available at: https://globalchangeaward.com/about-the-award/ [Accessed 12 2020].

Haigh, L., Lembachar, Y. & Gardien, K., 2020. Circle Economy- We can reimagine the brand-consumer relationship with circularity—let's make the most of it. [Online] Available at: https://www.circle-economy.com/blogs/we-can-reimagine-the-brand-consumer-relationship-with-circularity-lets-make-the-most-of-it [Accessed 11 2020].

Han S.LC., Henninger C.E., Apeagyei P., Tyler D. (2017) Determining Effective Sustainable Fashion Communication Strategies. In: Henninger C., Alevizou P., Goworek H., Ryding D. (eds) Sustainability in Fashion. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-319-51253-2 7 [Accessed 11 2020].

Hansen, W., Christopher, M. & Verbuecheln, M., 2002. EU Waste Policy and Challenges for Regional and Local Authorities. [Online] Available at: https://www.ecologic.eu/sites/files/download/projekte/1900-1949/1921-1922/1921-1922 background paper waste en.PDF [Accessed 01 2021].

Hare, M., n.d. texpertisenetwork.messefrankfurt-Recycling Textiles. [Online] Available at: https://texpertisenetwork.messefrankfurt.com/frankfurt/en/list/apparel-fabrics-fashion/texcycle-11-recycling-textiles.html [Accessed 11 2020].

Hartman, D., 2017. The Disadvantages of Recycled Plastics. [Online] Available at: https://sciencing.com/disadvantages-recycled-plastics-7254476.html [Accessed 01 2021].

Hawley, J. M., 2009. Understanding and improving textile recycling: a systems perspective, s.l.: Woodhead [Online], Available at: https://www.sciencedirect.com/science/article/pii/B9781845694531500085?via%3Dihub [Accessed 01 2021].

Heikkilä, P. (Ed.), Fontell, P., Kamppuri, T., Mensonen, A., Määttänen, M., Pitkänen, M., Raudaskoski, A., Vehmas, K., Vehviläinen, M., & Harlin, A. (2018). The Relooping Fashion Initiative. VTT Technical Research Centre of Finland. VTT Research Report No. VTT-R-01703-18 [Online] Available at: https://cris.vtt.fi/ws/portalfiles/portal/19258635/VTT R 01703 18.pdf [Accessed 11 2020].

Hemkhaus, et al., 2019. adelphi. [Online] Available at: www.adelphi.de/system/files/mediathek/bilder [Accessed 10 2020].

Henry, B., Laitala, K. & Klepp, I. G., 2019. Science of The Total Environment. Microfibres from apparel and home textiles: Prospects for including microplastics in environmental sustainability assessment, Volume 652, pp. 483-494. [Online] Available at: https://doi.org/10.1016/j.scitotenv.2018.10.166 [Accessed 11 2020].

Hepburn, S., 2015. Nike and Adidas show cautious support for eco-friendly dye technology, Guardian Sustainable business. [Online] Available at: https://www.theguardian.com/sustainable-business/sustainable-fashion-blog/2015/apr/24/nike-and-adidas-show-cautious-support-for-eco-friendly-dye-technology [Accessed 02 2021].

Higg Index Product Tools, n.d. Sustainable Apparel Coalition (SAC). [Online] Available at: https://product.higg.org/page/sustainable-apparel-coalition#sustainable-apparel-coalition [Accessed 02 2021].

Hildebrandt, J., Thrän, D. & Bezama, A., 2021. impacts of bio-based materials used within the manufacturing of selected leather substitutes, Journal of Cleaner Production, Volume 287. [Online] Available at: https://doi.org/10.1016/j.jclepro.2020.125470. [Accessed 01 2021].

HM group, 2018. Sustainability Report. [Online] Available at: https://about.hm.com/content/dam/hmgroup/groupsite/documents/masterlanguage/CSR/reports/2018 Sustainability report/HM Group SustainabilityReport 2018 %20FullReport.pdf [Accessed 11 2020].

HM group, n.d. Circularity and our value chain. [Online] Available at: https://hmgroup.com/sustainability/circular-and-climate-positive/circularity-and-our-value-chain/ [Accessed 11 2020].

HM group, n.d. Garment Collection, Recycle at H&M. [Online] Available at: https://www2.hm.com/en ie/ladies/shop-by-feature/16r-garment-collecting.html [Accessed 11 2020].

HOLLYROSE.ECO, 2020. Regenerative Agriculture and Fashion Brands. [Online] Available at: https://hollyrose.eco/2020/07/what-is-regenerative-farming-regenerative-fashion/ [Accessed 11 2020].

Hong Kong Research Institute of Textiles and Apparel - HKRITA, n.d. TECHNOLOGY INSIGHTS. [Online] Available at: https://www.hkrita.com/newsletter/issue50/tech-1-en.html [Accessed 11 2020].

Hong, M. & Chen, E. Y.-X., 2017. Chemically Recyclable Polymers: A Circular Economy Approach to Sustainability, Green Chemistry 19 (16), 3692–3706.. [Online] Available at: https://doi.org/10.1039/C7GC01496A [Accessed 02 2021].

Honolulu Board of Water Supply, 2003. Water recycling program, Using water wisely. [Online] Available at: https://www.boardofwatersupply.com/bws/media/files/publication-water-recycling-program-using-water-wisely-2003-03.pdf [Accessed 01 2021].

Hopewell, J., Dvorak, R. & Kosior, E., 2009. Plastics recycling: challenges and opportunities. Philosophical transactions of the royal society B, 364(1526), p. [Online] Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2873020/ [Accessed 01 2021].

Hu, E. et al., 2018. Minimizing Freshwater Consumption in the Wash-Off Step in Textile Reactive Dyeing by Catalytic Ozonation with Carbon Aerogel Hosted Bimetallic Catalyst. [Online] Available at: https://doi.org/10.3390/polym10020193 [Accessed 02 2021].

IMSA Amsterdam, 2013. Unleashing the Power of the Circular Economy. [Online] Available at: https://www.yumpu.com/en/document/view/14610882/unleashing-the-power-of-the-circular-economy [Accessed 10 2020].

INDITEX, 2016. Annual Report. [Online] Available at: https://www.inditex.com/documents/10279/319575/Inditex+Annual+Report+2016/6f8a6f55-ed5b-41f4-b043-6c104a305035 [Accessed 11 2020].

Innovation in textiles, 2020. Fibres/Yarns/Fabrics Why bio-based textiles and the circular economy are essential for the future of.... [Online] Available at: https://www.innovationintextiles.com/why-biobased-textiles-and-the-circular-economy-are-essential-for-the-future-of-fashion/ [Accessed 01 2021].

Innovation Textiles, 2018. Dyeing/Finishing/Printing ColorZen wins innovation competition. [Online] Available at: https://www.innovationintextiles.com/colorzen-wins-innovation-competition/ [Accessed 02 2021].

JAIN, M., 2017. Ecological approach to reduce carbon footprint of textile industry, International Journal of Applied Home Science, Volume 4 (7&8), 623-633, ISSN: 2394-1413. [Online] Available at: https://scientificresearchjournal.com/wp-content/uploads/2017/06/Home-Science-Vol-4 A-623-633-Full-Paper.pdf [Accessed 03 2021].

Kabir, S. M. F., Chakraborty, S., Hoque, S. M. A. & Mathur, K., 2019. Sustainability Assessment of Cotton-Based Textile Wet Processing, Clean Technol. 1(1), 232-246. [Online] Available at: https://doi.org/10.3390/cleantechnol1010016 [Accessed 02 2021].

Kang, M.-J. & Wimmer, R., 2008. Product service systems as systemic cures for obese consumption and production. [Online] Available at: https://www.sciencedirect.com/science/article/abs/pii/S095965260700176X?via%3Dihub [Accessed 10 2020].

Kant, R., 2012. Textile dyeing industry an environmental hazard, Vol.4, No.1, [Online] Available at: https://www.researchgate.net/publication/265893071 Textile dyeing industry an environmental hazard/fulltext/54aac2280cf2bce6aa1d615f/Textile-dyeing-industry-an-environmental-hazard.pdf? sg%5B0%5D=NOgkPdeFxtkJq9XM6fLmCikiLsEooKR1UU1IPq3jIzgtCog0e2PNpqJQnd3 [Accessed 01 2021].

Karas, S., n.d. How Regenerative Agriculture Could Help Clean Up the Fashion Industry. [Online] Available at: https://www.csuchico.edu/regenerativeagriculture/blog/regenerative-fiber-production.shtml [Accessed 11 2020].

Karthik, V., Balu, K., Haneef, M. & Mannarthippusulthan, M., n.d. Removal of dyes and metals using natural adsorbents, Journal of Chemical and Pharmaceutical Research, 2015, 7(3):77-82. [Online] Available at: https://www.researchgate.net/publication/306134690 Removal of dyes and metals using natural adsorbents [Accessed 01 2021].

Khatri, M. White,(2015) 5 - Sustainable dyeing technologies, Sustainable Apparel, Woodhead Publishing, Pages 135-160,[Online] Available at: http://www.sciencedirect.com/science/article/pii/B9781782423393000054 [Accessed 01 2021].

Kiran, S. et al., 2020. Agro-Waste Applications for Bioremediation of Textile Effluents, Recycling from waste in fashion and textiles, A sustainable and circular economic approach. [Online] Available at: https://dokumen.pub/recycling-from-waste-in-fashion-and-textiles-a-sustainable-and-circular-economic-approach-1nbsped-111962049x-9781119620495.html [Accessed 01 2021].

Knitting views Bangladesh, 2018. REVOLUTIONARY COLORZEN™ TECHNOLOGY MAKING DYEING PROCESS EFFICIENT AND ENVIRONMENTALLY FRIENDLY, Technology.. [Online] Available at: https://knittingviewsbd.com/revolutionary-colorzen-technology-making-dyeing-process-efficient-and-environmentally-friendly/ [Accessed 02 2021].

Kooistra, K., Termorshuizen, A. & Pyburn, R., 2006. The sustainability of cotton, Consequences for man and environment, Science Shop Wageningen UR. [Online] Available at: https://edepot.wur.nl/17214 [Accessed 02 2021].

Koszewska, M., 2018. Circular Economy — Challenges for the Textile and Clothing Industry, Autex Research Journal 18(4), LicenseCC BY-NC-ND. [Online] Available at: https://www.researchgate.net/publication/326546054 Circular Economy - Challenges for the Textile and Clothing Industry [Accessed 03 2021].

Krewitt, W. et al., 2002. Indicators for human toxicity in Life Cycle Impact Assessment Position paper for SETAC-Europe WIA2 Task Group on Human toxicity. [Online] Available at: https://www.researchgate.net/publication/224802600 Indicators for Human Toxi city in Life-Cycle Impact Assessment/stats [Accessed 03 2021].

Krikke, H., 2011. Impact of closed-loop network configurations on carbon footprint: A case study in copiers. [Online] Available at: https://www.researchgate.net/publication/232400616 Impact of closed-loop network configurations on carbon footprints A case study in copiers [Accessed 10 2020].

Kumar, D., Garje, A., Desai, K. & Gupta, D., 2010. Dyeing without water, Journal of the Textile Association 71(4):171-174. [Online] Available at: https://www.researchgate.net/publication/298003042 Dyeing without water [Accessed 02 2021].

Kumar, J. et al., 2020. Solutions for Sustainable Fashion and Textile Industry, Recycling from waste in fashion and textiles-A Sustainable and Circular Economic Approach, Scrivener publishing,. [Online] Available at: https://dokumen.pub/qdownload/recycling-from-waste-in-fashion-and-textiles-a-sustainable-and-circular-economic-approach-9781119620495-111962049x-9781119620518-1119620511-9781119620525-111962052x-9781119620532-1119620538.html [Accessed 01 2021].

Kumar, R. S., 2015. Process management in spinning. Broken sound parkway NW: CRC press. [Online] Available at: https://vdocuments.net/process-management-in-spinning-rsenthil-kumar-58f9ad4e4bd03.html [Accessed 10 2020].

Lacy, P., Long, J. & Spindler, W., 2020. THE CIRCULAR ECONOMY HANDBOOK. In: Realizing the circular advantage. UK: Palgrave Macmillan, pp. 301-304; [Online] Available at: https://www.researchgate.net/publication/342895241 Peter Lacy Jessica Long Wesley Spindler The circular economy handbook Realizing the circular adva ntage Palgrave Macmillan UK 2020 [Accessed 12 2020].

Lagashetti, A. C., Dufossé, L., Singh, S. K. & Singh, P. N., 2019. Fungal Pigments and Their Prospects in Different Industries, Microorganisms. [Online] Available at: https://doi.org/10.3390/microorganisms7120604 [Accessed 02 2021].

Leahy, S., 2014. Your Water Footprint : The Shocking Facts About How Much Water We Use to Make Everyday Products. Buffalo,: Firefly Books. [Online] Available at: https://www.scribd.com/book/278378147/Your-Water-Footprint-The-Shocking-Facts-About-How-Much-Water-We-Use-to-Make-Everyday-Products [Accessed 02 2021].

Lechleitner, A. et al., 2020. Chemisches Recycling von gemischten Kunststoffabfällen als ergänzender Recyclingpfad zur Erhöhung der Recyclingquote. Österr Wasser- und Abfallw 72, 47–60. [Online] Available at: https://doi.org/10.1007/s00506-019-00628-w [Accessed 02 2021].

Lehmann, M. et al., 2019. Pulse of the fashion industry, s.l.: Global Fashion Agenda; Boston Consulting Group; Sustainable Apparel Coalition. Available at: http://media-publications.bcg.com/france/Pulse-of-the-Fashion-Industry2019.pdf [Accessed 11 2020].

Ley, K. et al., 2020. FINANCING the Transformation in the Fashion Industry - Unlocking Investment to Scale Innovation, s.l.: FASHION FOR GOOD & BOSTON CONSULTING GROUP; [Online] Available at: https://fashionforgood.com/wp-content/uploads/2020/01/FinancingTheTransformation Report Digital FINAL Em bargo compressed.pdf [Accessed 12 2020].

Li, Z., 2016. Development and perspective of bio-based chemical fiber industry. [Online] Available at: http://doi.cnki.net/Resolution/Handler?doi=10.13345/j.cjb.160050 [Accessed 01 2021].

Lin, Y., Zhang, Z., Wu, F. & Deng, N., 2004. DEVELOPMENT OF ECOLOGICAL INDUSTRIAL PARKS IN CHINA. Fresenius Environmental Bulletin, 13(7), pp. 600 - 606; [Online] Available at: https://www.researchgate.net/publication/297285874 Development of Ecological Industrial Parks in China; [Accessed: 12 2020].

Lindex, 2019. Sustainability report. [Online]Available at: https://about.lindex.com/files/documents/lindex-sustainability-report-2019.pdf [Accessed 11 2020].

Lovins, H., 2017. 3 circular principles for healthy agriculture. [Online] Available at: https://www.greenbiz.com/article/3-circular-principles-healthy-agriculture [Accessed 11 2020].

Lu, D. S., 2018. Changing trends in world textile and apparel trade. [Online] Available at: https://www.just-style.com/analysis/changing-trends-in-world-textile-and-apparel-trade id134353.aspx [Accessed 11 2020].

Määttänen, M. et al., 2019. Colour management in circular economy: decolourization of cotton waste. Research Journal of Textile and Apparel, 23(2), pp. [Online] Available at: https://www.emerald.com/insight/content/doi/10.1108/RJTA-10-2018-0058/full/pdf?title=colour-management-in-circular-economy-decolourization-of-cotton-waste [Accessed 01 2021].

MacCarthy, B. & Jayarathne, P. S., 2010. Fast Fashion: Achieving Global Quick Response (GQR) in the Internationally Dispersed Clothing Industry. [Online] Available at: https://www.researchgate.net/publication/226021296 Fast Fashion Achieving Gl obal Quick Response GQR in the Internationally Dispersed Clothing Industry [Accessed 10 2020].

Made Trade, 2019. Behind the Fiber: Transforming Banana Tree Waste Into Fabric. [Online] Available at: https://medium.com/@madetrade/behind-the-fiber-transforming-banana-tree-waste-into-fabric-a33eb343d298 [Accessed 01 2021].

Makower, J., 2017. How C&A created the world's first Cradle to Cradle T-shirt. [Online] Available at: https://www.greenbiz.com/article/how-ca-created-worlds-first-cradle-cradle-t-shirt [Accessed 02 2021].

Mani, S., Chowdhary, P. & Bharagava, R. N., 2019. Textile Wastewater Dyes: Toxicity Profile and Treatment Approaches. In: Bharagava R., Chowdhary P. (eds) Emerging and Eco-Friendly Approaches for Waste Management. Springer, Singapore.. [Online] Available at: https://doi.org/10.1007/978-981-10-8669-4 11 [Accessed 01 2021].

Manjula, B. et al., 2017. Polyolefin Fibres (Second Edition) Structure, Properties and Industrial Applications, The Textile Institute Book Series, Editor: Samuel C.O. Ugbolue, Pages 539-560. [Online] Available at: https://doi.org/10.1016/B978-0-08-101132-4.00018-7 [Accessed 02 2021].

Manshoven, S. et al., 2019. eionet.europa.eu - Textiles and the environment in a circular economy. [Online] Available at: https://www.eionet.europa.eu/etcs/etc-wmge/products/etc-reports/textiles-and-the-environment-in-a-circular-economy [Accessed 11 2020].

Marketing-insider, 2017. Characteristics of the Product Life Cycle Stages and their Marketing Implications. [Online] Available at: https://marketing-insider.eu/characteristics-of-the-product-life-cycle-stages/ [Accessed 11 2020].

MATERIAL CONNEXION, 2019. Giving Waste a Second Life. [Online] Available at: https://materialconnexion.com/giving-waste-a-second-life/ [Accessed 02 2021].

Maxwell, D. D., McAndrew & Ryan, 2015. The state of the apparel sector, s.l.: The sustainable business group. Mcdonough, n.d. William McDonough » Cradle to Cradle. [Online] Available at: https://mcdonough.com/cradle-to-cradle/ [Accessed 11 2020].

MCKAY, G., PORTER, J. F. & PRASAD, G. R., 1998. THE REMOVAL OF DYE COLOURS FROM AQUEOUS SOLUTIONS BYADSORPTION ON LOW-COST MATERIALS. [Online] Available at: https://www.academia.edu/18936956/The removal of dye colours from aqueou s solutions by adsorption on low cost materials [Accessed 01 2021].

McKinlay, R., 2019. Chemical recycling offers major potential for plastic packaging, Recycling International. [Online] Available at: https://recyclinginternational.com/technology/chemical-recycling-offers-major-potential-for-plastic-packaging/27894/ [Accessed 02 2021].

McKinsey & Company, 2016. Why the circular economy is all about retaining value. [Online] Available at: https://www.mckinsey.com/business-functions/sustainability/our-insights/why-the-circular-economy-is-all-about-retaining-value [Accessed 11 2020].

McKinsey & Company, 2019. Fashion's new must-have: sustainable sourcing at scale, Apparel, Fashion & Luxury Group, McKinsey Apparel CPO Survey 2019. [Online] Available at:

https://www.mckinsey.com/~/media/mckinsey/industries/retail/our%20insights/fashions%20new%20must%20have%20sustainable%20sourcing%20at%20scale/fashions-new-must-have-sustainable-sourcing-at-scale-vf.ashx [Accessed 02 2021].

McKone, T. E. & Hertwich, E. G., 2001. The human toxicity potential and a strategy for evaluating model performance in life-cycle impact assessment,Lawrence Berkeley National Laboratory. [Online] Available at: https://www.researchgate.net/publication/225765816 Human Toxicity Potential I nLCA Selected Papers InLCA Selected Papers The Human Toxicity Potentia l and a Strategy for Evaluating Model Performance in Life Cycle Impact As sessment [Accessed 01 2021].

Mentink, B., 2020. A Brief History of the Circular Economy. [Online] Available at: http://recover-e.nl/brief-history-circular-economy/ [Accessed 01 2021].

Merdan, N., Eyupoglu, S. & Duman, M. N., 2017. Ecological and Sustainable Natural Dyes, Textiles and Clothing Sustainability, Editor: Subramanian Senthilkannan Muthu. [Online] Available at: https://books.google.de/books?hl=en&lr=&id=gWDSDAAAQBAJ&oi=fnd&pg=PR5&dq=sustainable+clothing+wet+processing+challenges&ots=UzjK-kVtrT&sig=lbomC4v54bMZA5z7AUt91xckii0#v=onepage&q&f=false [Accessed 02 2021].

Messe frankfurt, n.d. Recycling Textiles. [Online] Available at: https://texpertisenetwork.messefrankfurt.com/frankfurt/en/list/apparel-fabrics-fashion/texcycle-11-recycling-textiles.html c

Meys, R. et al., 2020. Towards a circular economy for plastic packaging wastes – the environmental potential of chemical recycling, Resources, Conservation and Recycling, Volume 162, ISSN 0921-3449.. [Online] Available at: https://www.sciencedirect.com/science/article/pii/S092134492030327X?via%3Dihub [Accessed 02 2021].

Michaud, J.-C.et al., 2010. Environmental benefits of recycling – 2010 update, WRAP, Final Report. [Online] Available at: http://117.239.19.55:8080/xmlui/handle/123456789/174 [Accessed 02 2021].

Michel, F. & Kaelble, S., 2020. Detoxing the Fashion Industry For Dummies®, Limited Edition, John Wiley & Sons, Ltd.. [Online] Available at: https://www.roadmaptozero.com/dummy-book [Accessed 01 2021].

Mika Sillanpää, C. N., 2019. The Circular Economy: Case Studies about the transition from the Linear Economy, Finland: Candice Janco. [Online] Available at: https://www.sciencedirect.com/book/9780128152676/the-circular-economy?via=ihub [Accessed 11 2020].

Milans, F. H., 1988. Degradable Plastics - Report to the Chairman, Committee on Governmental Affairs, U.S. Senate, Washington D.D.: [Online] Available at: https://books.google.de/books?id=EkkFtApBmZgC&pg=PA12&lpg=PA12&dq=Degradable+plastic&source=bl&ots=mkov6FR8-l&sig=ACfU3U1GlzBQAfigo2EDAZ-

eJYCg6N5 PA&hl=en&sa=X&ved=2ahUKEwjGnaHS8JbuAhXBDmMBHR [Accessed 01 2021].

Mistra Future Fashion, n.d. how to design for circular economy?. [Online] Available at: http://mistrafuturefashion.com/what-we-do/#theme 1 [Accessed 01 2021].

Mogilireddy, V., 2018. Sustainable dyeing innovations: Greener ways to color textiles. [Online] Available at: https://www.prescouter.com/2018/11/sustainable-dyeing-innovations-greener-ways-color-textiles/ [Accessed 02 2021].

Morone, P. & Yilan, G., 2020. A Paradigm Shift in Sustainability: from Lines to Circles, ACTA INNOVATIONS, Editor in Chief: Rafał Marcin Łukasik, Ph.D. Research and Innovation Centre Pro-Akademia, 9/11 Innowacyjna Street, 95-050 Konstantynów Łódzki, Poland. [Online] Available at: https://doi.org/10.32933/ActaInnovations.36.1 [Accessed 02 2021].

Motte, H. d. l. & Palme, A., 2018. The development of the Blend Re:wind process. [Online] Available at: http://mistrafuturefashion.com/wp-content/uploads/2018/06/Mistra-Future-Fashion-2018-5-H.-dl.-Motte.-Blend-Re-wind.pdf [Accessed 11 2020].

Munford, L., 2020. Are polybags still in fashion? Packaging Europe. [Online] Available at: https://packagingeurope.com/are-polybags-still-in-fashion/ [Accessed 02 2021].

Murray, A., Skene, K. & Haynes, K., 2015. The Circular Economy: An interdisciplinary exploration of the concept and its application in a global context. [Online] Available at: https://doi.org/10.1007/s10551-015-2693-2 [Accessed 10 2020].

NATIONAL GEOGRAPHIC, 2018. NATIONAL GEOGRAPHIC SOCIETY NEWSROOM: 7 Things You Didn’t Know About Plastic (and Recycling). [Online] Available at: https://blog.nationalgeographic.org/2018/04/04/7-things-you-didnt-know-about-plastic-and-recycling/ [Accessed 01 2021].

Natural Resources Defense Council - NRDC, 2009. Ocean Acidification: The Other CO2 Problem. [Online] Available at: https://www.nrdc.org/sites/default/files/NRDC-OceanAcidFSWeb.pdf [Accessed 01 2021].

Nature research, n.d. nature. [Online] Available at: https://www.nature.com/articles/d42473-019-00359-2 [Accessed 10 2020].

Newman, M. C., 2010. Fundamentals of Ecotoxicology, 3rd edition, CRC press. [Online] Available at: https://books.google.de/books?hl=en&lr=&id=sg SBQAAQBAJ&oi=fnd&pg=PP1&dq=Fundamentals+of+ecotoxicology&ots=B4XZeIThUy&sig=SJKLqb12kLJyyxHotka2QDH6JP4#v=onepage&q&f=false [Accessed 01 2021].

Niinimäki, K., 2010. Eco-Clothing, Consumer Identity and Ideology. [Online] Available at:

https://www.researchgate.net/profile/Kirsi Niinimaeki/publication/227650874 Eco-Clothing Consumer Identity and Ideology/links/56ab227308aed5a013596505.pdf [Accessed 11 2020].

Nike, n.d. Bag to Better Program. [Online] Available at: https://purpose.nike.com/bag-to-better [Accessed 02 2021].

Office for Social Responsibility of the China National Textile and Apparel Council - CNTAC, 2020. Make Fashion Circular: Outlook for a New Textile Economy in China. [Online] Available at: https://www.ellenmacarthurfoundation.org/assets/downloads/Make-Fashion-Circular%EF%BC%9AOutlook-for-A-New-Textile-Economy-20201021.pdf [Accessed 11 2020].

Office for Social Responsibility of the China National Textile and Apparel Council (CNTAC); Ellen MacArthur Foundation; Lenzing, 2020. Make Fashion Circular, Outlook for a new textile economy in CHINA. [Online] Available at: https://www.ellenmacarthurfoundation.org/assets/downloads/Make-Fashion-Circular：Outlook-for-A-New-Textile-Economy-20201021.pdf [Accessed 02 2021].

Ogugbue, C. J. & Sawidis, T., 2011. Bioremediation and Detoxification of Synthetic Wastewater Containing Triarylmethane Dyes by Aeromonas hydrophila Isolated from Industrial Effluent,Biotechnology Research International Volume 2011, Article ID 967925, 11 pages. [Online] Available at: https://downloads.hindawi.com/archive/2011/967925.pdf [Accessed 01 2021].

Olsson, E., Posner, S., Roos, S. & Wilson, K., 2009. Kartläggning av kemikalieanvändning i kläder. Mölndal, Sweden.. [Online] Available at: https://docplayer.se/6002218-Swerea-ivf-uppdragsrapport-09-52-kartlaggning-av-kemikalieanvandning-i-klader-elisabeth-olsson-stefan-posner-sandra-roos-karin-wilson.html [Accessed 01 2021].

Organisation for Economic Co-operation and Development-OECD, 2020. Environment at a Glance: Climate change. [Online] Available at: https://www.oecd.org/environment/environment-at-a-glance/Circular-Economy-Waste-Materials-Archive-February-2020.pdf [Accessed 01 2021].

Östlund, Å., 2015. Textilåtervinning. Stockholm: Naturvårdsverket. [Online] Available at: https://www.naturvardsverket.se/Documents/publikationer6400/978-91-620-6685-7.pdf?pid=15536 [Accessed 11 2020].

Oxfam, 2020. Oxfamapps-second hand September. [Online] Available at: https://oxfamapps.org/secondhandseptember/ [Accessed 11 2020].

Palme, A., Idström, A., Nordstierna, L. & Brelid, H., 2014. Chemical and ultrastructural changes in cotton cellulose induced by laundering and textile use. [Online] Available at: https://link.springer.com/article/10.1007/s10570-014-0434-9 [Accessed 01 2021].

Pandey, R., Pandit, P., Pandey, S. & Mishra, S., 2020. Solutions for Sustainable Fashion and Textile Industry, Recycling from waste in fashion and textiles-A

Sustainable and Circular Economic Approach, Scrivener publishing,. [Online] Available at: https://dokumen.pub/qdownload/recycling-from-waste-in-fashion-and-textiles-a-sustainable-and-circular-economic-approach-9781119620495-111962049x-9781119620518-1119620511-9781119620525-111962052x-9781119620532-1119620538.html [Accessed 01 2021].

Partnership for Sustainable Textiles, n.d. Chemical and Environmental Management, Know-How. [Online] Available at: https://www.textilbuendnis.com/en/know-how/branchen-risiken/chemikalien-und-umweltmanagement/ [Accessed 01 2021].

Patagonia, 2018. 2018 environmental + social initiatives. [Online] Available at: https://issuu.com/thecleanestline/docs/patagonia-enviro-initiatives-2018 [Accessed 12 2020].

Patagonia, n.d. Patagonia's Plastic Packaging: A Study on the Challenges of Garment Delivery. [Online] Available at: https://eu.patagonia.com/de/en/stories/patagonias-plastic-packaging-a-study-on-the-challenges-of-garment-delivery/story-17927.html [Accessed 02 2021].

Patagonia, 2012. PVC Printing Inks and Phthalates. [Online] Available at: https://www.patagonia.com/on/demandware.static/Sites-patagonia-us-Site/Library-Sites-PatagoniaShared/en US/PDF-US/pvc printing inks and phtalates.pdf [Accessed 02 2021].

Patterson, P., 2020. Chemical Circularity in Fashion, commission by Laudes Foundation.. [Online] Available at: https://www.laudesfoundation.org/en/resources/2020/05/chemical-circularity-digital.pdf [Accessed 02 2021].

Payne, A., 2015. Open- and closed-loop recycling of textiles and apparel products, Handbook of Life Cycle Assessment (LCA) of Textiles and Clothing, Woodhead publishing Series in Textiles, P 103-123. [Online] Available at: https://books.google.de/books?id=v8LlBwAAQBAJ&pg=PA123&lpg=PA123&dq=Open-+and+closed-loop+recycling+of+textile+and+apparel+products+pdf&source=bl&ots=8viywmoj-v&sig=ACfU3U2pBwgoJRMDEbFhrqhgFrzlV b3cQ&hl=en&sa=X&ved=2ahUKEwipscSRqqruAhVS16QKHcR8ARA4RhDoATA [Accessed 01 2021].

Pearce, D. W. & Turner, R. K., 1990. Economics of natural resources and the environment. [Online] Available at: https://www.researchgate.net/publication/31662420 Economics of natural resources and the environment DW Pearce RK Turne [Accessed 11 2020].

Peteghem, D. V. & Mohout, O., 2018. Corporate Venturing: Accelerate growth through collaboration with startups. s.l.:Die Keure Publishing [Online] Available at: https://books.google.de/books/about/Corporate Venturing.html?id=yhheDwAAQBAJ&printsec=frontcover&source=kp read button&redir esc=y#v=onepage&q&f=false [Accessed 12 2020].

Plastics Recyclers Europe-RecyClass, 2017. Transparent Natural Flexible films guidelines. [Online] Available at: https://recyclass.eu/wp-content/uploads/2019/07/PP-Transparent-Natural-Flexible-films-guidelines-15-12-2017.pdf [Accessed 01 2021].

Plastics Recyclers Europe, 2018. Activities Report. [Online] Available at: https://www.sirespa.com/wp-content/uploads/2019/02/Activities-Brochure-2018-Final-version-1.pdf [Accessed 01 2021].

Plastics Recyclers Europe, 2019. Flexible Polyethylene Recycling in Europe, Accelerating the transition towards circular economy. [Online] Available at: https://www.pac.gr/bcm/uploads/flexible-pe-recycling-in-europe june-2019.pdf [Accessed 01 2021].

PlasticsEurop, 2018. Plastics-the Facts, An analysis of European plastics production, demand and waste date. [Online] Available at: https://www.plasticseurope.org/application/files/6315/4510/9658/Plastics the facts 2018 AF web.pdf [Accessed 02 2021].

PlasticsEurope, n.d. POLYOLEFINS, ABOUT PLASTICS. [Online] Available at: https://www.plasticseurope.org/en/about-plastics/what-are-plastics/large-family/polyolefins [Accessed 02 2021].

Po, M. et al., 2005. Predicting Community Behaviour in Relation to Wastewater Reuse-What Drives Decisions to Accept or Reject?. Perth, Western Australia: CSIRO Land & Water.. [Online] Available at: https://www.researchgate.net/publication/242602980 Predicting Community Behaviour in Relation to Wastewater Reuse What Drives Decisions to Accept or Reject/citations [Accessed 01 2021].

Policy Hub, 2019. Circularity for apparel and footwear. [Online] Available at: https://assets-global.website-files.com/5dcda718f8a683895d9ea394/5df141c17f7e4e59af1c8eea Building%20blocks%20for%20a%20sustainable%20circular%20economy%20for%20-%20December%202019.pdf [Accessed 02 2021].

Preston, F., 2012. A Global Redesign? Shaping the Circular Economy. [Online] Available at: https://scholar.google.de/scholar?q=Preston,+F.,+2012.+A+Global+Redesign%3F+Shaping+the+Circular+Economy.&hl=en&as sdt=0&as vis=1&oi=scholart [Accessed 10 2020].

PWC-PricewaterhouseCoopers, 2018. Closing the loop – the circular economy, what it means and what it can do for you. [Online] Available at: https://www.pwc.com/hu/en/kiadvanyok/assets/pdf/Closing-the-loop-the-circular-economy.pdf [Accessed 11 2020].

PWC-PricewaterhouseCoopers, 2019. The road to circularity. [Online] Available at: https://www.pwc.de/de/nachhaltigkeit/pwc-circular-economy-study-2019.pdf [Accessed 11 2020].

Quantis, 2018. MEASURING FASHION, Environmental Impact of the Global Apparel and Footwear Industries Study. [Online] Available at: https://refashion.fr/eco-design/sites/default/files/fichiers/Measuring%20Fashion%20Environmental%20Impact%20of%20the%20Global%20Apparel%20and%20Footwear%20Industries%20Study.pdf [Accessed 01 2021].

Quick, S. et al., 2013. Cross-European survey - Final Report. [Online] Available at: https://issuu.com/civicagenda/docs/260113096 cross-european libraries survey report f [Accessed 10 2020].

R., M. & Chertow, 2000. INDUSTRIAL SYMBIOSIS: Literature and Taxonomy. Annual Review of Energy and the Environment, Issue 25, pp. 313-37 [Online] Available at: https://pdfs.semanticscholar.org/1a5f/dc68ba3eb4a8b61e2237401a8b0a813bb693.pdf? ga=2.214680209.746154345.1607719851-92211936.1607719851 [Accessed: 12 2020].

R.Rathinamoorthy, 2019. Circular Economy in Textiles and Apparel (Processing, Manufacturing and Design). In: S. S. Muthu, ed. s.l.:Woodhead Publishing, pp. 13-48 [Online], Available at: https://www.sciencedirect.com/science/article/pii/B9780081026304000029 [Accessed: 12 2020].

Ranta, V. & Saari, U. A., 2019. Circular Economy: Enabling the Transition towards Sustainable Consumption and Production, s.l.:Springer, Cham. [Online] Available at: https://doi.org/10.1007/978-3-319-71062-4 3-1 [Accessed at: 12 2020].

Rearick, W. A., Farias, L. T. & Goettsch, G., 1995. Water and salt reuse in the dyehouse, Cotton Incorporated. [Online] Available at: https://p2infohouse.org/ref/30/29153.pdf [Accessed 01 2021].

Reflow, n.d. PIÑATEX, AN INNOVATIVE NATURAL TEXTILE MADE FROM WASTE PINEAPPLE LEAF FIBRE. [Online] Available at: https://reflowproject.eu/best-practices/pinatex-an-innovative-natural-textile-made-from-waste-pineapple-leaf-fibre/ [Accessed 01 2021].

ReportLinker, 2020. Global Green Chemicals Industry, MARKET IMPACT SURVEY - COVID-19 & LOOMING RECESSION. [Online] Available at: https://www.reportlinker.com/p05817995/Global-Green-Chemicals-Industry.html?utm source=GNW [Accessed 02 2021].

Richards, P., 2015. Fabric Finishing: Dyeing And Colouring, Woodhead Publishing Series in Textiles, Pages 497-498. [Online] Available at: https://coek.info/pdf-fabric-finishing-.html [Accessed 01 2021].

Roadmap to Zero, 2016. What is the difference between an RSL and an MRSL? - The Importance of a Single, Unified MRSL. [Online] Available at: https://www.roadmaptozero.com/post/the-importance-of-a-single-unified-mrsl [Accessed 01 2021].

Roadmap to zero, n.d. ZDHC Manufacturing Restricted substance list, ZDHC MRSL V2.0. [Online] Available at: https://mrsl.roadmaptozero.com/?guidance=1 [Accessed 02 2021].

Robinson, T., McMullan, G., Marchant, R. & Nigam, P., 2000. Remediation of dyes in textile effluent: a critical review on current treatment technologies with a proposed alternative, Biotechnology Research Group, School of Applied Biological and Chemical Sciences, University of Ulster, Coleraine, BT52 1SA, UK. [Online] Available at: https://www.academia.edu/1891708/Remediation of dyes in textile effluent a c ritical review on current treatment technologies with a proposed alternative [Accessed 01 2021].

Roos, S. et al., 2019. white paper on textile recycling. [Online] Available at: https://www.researchgate.net/publication/337111016 White paper on textile rec ycling [Accessed 01 2021].

ROOS, S., 2015. Towards Sustainable Use of Chemicals in the Textile Industry: How life cycle assessment can contribute,THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING,Department of Chemistry and Chemical Engineering CHALMERS UNIVERSITY OF TECHNOLOGY Gothenburg, Sweden. [Online] Available at: https://www.semanticscholar.org/paper/Towards-Sustainable-Use-of-Chemicals-in-the-Textile-Roos/a73949b06b92048964423d452c915666f002a052 [Accessed 01 2021].

Rosen, M. A., 2016. implementation of Circular Economy Business Models by Small and Medium-Sized Enterprises (SMEs): Barriers and Enablers. [Online] Available at: https://www.mdpi.com/2071-1050/8/11/1212 [Accessed 10 2020].

Saicheua, V., Knox, A. & Cooper, T., 2012. Sustainability in Clothing Supply Chain –Implications for Marketing. [Online] Available at: https://scholar.google.de/scholar?q=Sustainability+in+Clothing+Supply+Chain+%E 2%80%93Implications+for+Marketing&hl=en&as sdt=0&as vis=1&oi=scholart [Accessed 10 2020].

Šajn, N., 2019. Environmental impact of the textile and clothing industry. [Online] Available at: https://www.europarl.europa.eu/RegData/etudes/BRIE/2019/633143/EPRS BRI(2 019)633143 EN.pdf [Accessed 01 2021].

SALABERT, S., 2020. How prAna squelched polybags. [Online] Available at: https://www.snewsnet.com/gear/how-prana-squelched-polybags [Accessed 02 2021].

Salgot, M. & Folch, M., 2018. Wastewater treatment and water reuse, Environmental Science & Health. [Online] Available at: https://daneshyari.com/article/preview/8940613.pdf [Accessed 01 2021].

Sandin, G. & Peters, G. M., 2018. Environmental impact of textile reuse and recycling - A review (Journal of Cleaner Production). [Online] Available at:

https://www.sciencedirect.com/science/article/pii/S0959652618305985 [Accessed 01 2021].

Sandin, G., Roos, S. & Johansson, M., 2019. environmental impact of textile fibers – what we know and what we don't know. [Online] Available at: http://mistrafuturefashion.com/wp-content/uploads/2019/03/Sandin-D2.12.1-Fiber-Bibel-Part-2 Mistra-Future-Fashion-Report-2019.03.pdf [Accessed 10 2020].

Sawhney, P. et al., 2010. Scope of nanotechnology in modern textiles. World Journal of Engineering, Volume 7, pp. 1-18. [Online] Available at: https://www.researchgate.net/publication/254257263 Scope of nanotechnology in modern textiles [Accessed 10 2020].

Schmidt, A. et al., 2016. Gaining benefits from discarded textiles - LCA of different treatment pathways. [Online] Available at: http://norden.diva-portal.org/smash/get/diva2:957517/FULLTEXT02.pdf [Accessed 01 2021].

Schuch, A. B., 2016. THE CHEMICAL RECYCLE OF COTTON. [Online] Available at: https://www.researchgate.net/publication/329240913 The chemical recycle of cotton [Accessed 01 2021].

Scott, A., 2015. Cutting Out Textile Pollution - Cleaning up one of the world's dirtiest industries will require new technology and more. [Online] Available at: https://cen.acs.org/articles/93/i41/Cutting-Textile-Pollution.html [Accessed 01 2021].

Segran, E., n.d. Fashion's plastic problem is bigger than you can imagine—but this brand is finding new ways to solve it. [Online] Available at: https://www.fastcompany.com/90325711/everlanes-founder-vowed-to-remove-all-new-plastic-from-the-brands-supply-chain-by-2021-now-he-has-to-figure-out-how [Accessed 02 2021].

Singh, Z. & Bhalla, S., 2017. Toxicity of Synthetic Fibres & Health, Volume 2 Issue 1. [Online] Available at: https://www.researchgate.net/publication/316044390 Toxicity of Synthetic Fibres and Human Health OPEN ACCESS [Accessed 01 2021].

Singha, K., Maity, S. & Singha, M., 2012. The Salt-Free Dyeing on Cotton: An Approach to Effluent Free Mechanism; Can Chitosan be a Potential Option?,International Journal of Textile Science, 1(6): 69-77. [Online] Available at: http://article.sapub.org/10.5923.j.textile.20120106.03.html [Accessed 01 2021].

Smits, H., Cunningham, G. & Spath, T., n.d. Circle textiles closing the loop for workwear. [Online] Available at: https://docplayer.net/45947283-Circle-textiles-closing-the-loop-forworkwear.html [Accessed 10 2020].

Solverchem, n.d. ARTICLES / WHAT IS STABILIZING AGENT IN TEXTILE | FUNCTIONS OF STABILIZING AGENT, Solver chem publications. [Online] Available at: https://www.solverchem.com/articles/endustrial-products-articles-

1/what-is-stabilizing-agent-in-textile-functions-of-stabilizing-agent/details [Accessed 03 2021].

Soutter, W., 2012. Nanotechnology in Clothing. [Online] Available at: https://www.azonano.com/article.aspx?ArticleID=3129 [Accessed 11 2020].

Spring wise, 2020. Innovations That Matter - Circular fashion software company creates bespoke, sustainable T-Shirts. [Online] Available at: https://www.springwise.com/sustainability-innovation/fashion-beauty/teemill-circular-fashion-open-source-advertising [Accessed 11 2020].

Sulyman, M., Namiesnik, J. & Gierak, A., n.d. Low-cost Adsorbents Derived from Agricultural By-products/Wastes for Enhancing Contaminant Uptakes from Wastewater: A Review, Pol. J. Environ. Stud. Vol. 26, No. 2 (2017), 479-510. [Online] Available at: https://doi.org/10.15244/pjoes/66769 [Accessed 01 2021].

Sung, K. (2015) A review on upcycling: current body of literature, knowledge gaps and a way forward. Proceedings of the 17th International Conference on Environment, Cultural, Economic and Social Sustainability, Venice, 13-14 April, pp. 28-40 [Online] Available at: https://dora.dmu.ac.uk/bitstream/handle/2086/14640/2015-Sung-a%20review%20on%20upcycling-current%20body%20of%20literature%2c%20knowledge%20gaps%20and%20a%20way%20forward.pdf?sequence=1&isAllowed=y [Accessed 11 2020].

Sustainability.C&A, 2018. Global Sustainability Report 2018. [Online] Available at: https://sustainability.c-and-a.com/uk/en/sustainability-report/2018/sustainable-products/circular-fashion/circular-fashion-products/ [Accessed 11 2020].

Sustainable Apparel Coalition-Press Release, n.d. New Tool Assesses Environmental Impacts of Finished Products, Rounding Out Core Higg Index Suite. [Online] Available at: https://apparelcoalition.org/press-releases/higg-pm-2020-launch/ [Accessed 02 2021].

Sustainable Apparel Coalition, n.d. Higg Facility Tools. [Online] Available at: https://apparelcoalition.org/higg-facility-tools/ [Accessed 02 2021].

Sustainable Apparel Coalition, n.d. The Higg Index. [Online] Available at: https://apparelcoalition.org/the-higg-index/ [Accessed 02 2021].

Sustainable Apparel Coalition; Outdoor Industry Association, 2016. Facility Social Labor Module (FSLM). [Online] Available at: https://outdoorindustry.org/wp-content/uploads/2016/08/5.-Facility-Social-Labor-Module-Convergence.pdf [Accessed 02 2021].

Sutthivaiyakit, P., Achatz, S., Lintelmann, J. et al. LC-MS/MS method for the confirmatory determination of aromatic amines and its application in textile analysis. Anal Bioanal Chem 381, 268–276 (2005). [Online] Available at: https://doi.org/10.1007/s00216-004-2852-2 [Accessed 02 2021].

Swedish Chemicals Agency - KEMI, 2014. Chemicals in textiles – Risks to human health and the environment. [Online] Available at: https://www.kemi.se/download/18.6df1d3df171c243fb23a98f3/1591454110491/rapport-6-14-chemicals-in-textiles.pdf [Accessed 01 2021].

Synthetic Biology Leadership Council, 2012. Synthetic Biology Roadmap for the UK. [Online] Available at: https://www.gov.uk/government/groups/synthetic-biology-leadership-council#synthetic-biology-roadmap-for-the-uk-2012 [Accessed 02 2021].

Szaky, T., 2014. Finding recycling solutions for commercial packaging waste. [Online] Available at: https://www.packagingdigest.com/sustainability/finding-recycling-solutions-commercial-packaging-waste [Accessed 02 2021].

Szaky, T., 2014. Finding recycling solutions for commercial packaging waste, Packaging Digest. [Online] Available at: https://www.packagingdigest.com/sustainability/finding-recycling-solutions-commercial-packaging-waste [Accessed 02 2021].

Tattara, G. & Crestanello, P., 2009. A Global Network and its Local Ties. Restructuring of the Benetton Group,. [Online] Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract id=1397103 [Accessed 01 2021].

Taylor, T., 2020. conversable economist - Product Longevity and Planned Obsolescence. [Online] Available at: https://conversableeconomist.blogspot.com/2020/04/product-longevity-and-planned.html [Accessed 11 2020].

TEDA, n.d. Tianjin Economic and Technical Development Area. [Online] Available at: https://teda.gov.cn [Accessed 12 2020].

TERRACYCLE, n.d. Plastic Packaging Zero Waste Box™ Recycle plastic packaging through this Zero Waste Box.. [Online] Available at: https://www.terracycle.com/en-US/zero waste boxes/plastic-packaging [Accessed 01 2021].

Tetteh, E. et al., 2019. Treatment of Water and Wastewater for Reuse and Energy Generation-Emerging Technologies,. [Online] Available at: https://www.researchgate.net/publication/332817151 Treatment of Water and Wastewater for Reuse and Energy Generation-Emerging Technologies [Accessed 01 2021].

Textile Consult, n.d. Sustainable fashion: Is textile recycling the answer?. [Online] Available at: https://www.textileconsult.co.uk/2018/08/23/sustainable-fashion-is-textile-recycling-the-answer/ [Accessed 01 2021].

Textile Exchange, 2019. Preferred Fiber & Materials Market Report, s.l.: s.n. [Online] Available at: https://textileexchange.org/wp-content/uploads/2019/11/Textile-Exchange Preferred-Fiber-Material-Market-Report 2019.pdf [Accessed 11 2020].

Textile Guide, Chemsec, n.d. Textiles come with a toxic footprint. [Online] Available at: https://textileguide.chemsec.org/find/textiles-come-with-a-toxic-footprint/ [Accessed 02 2021].

The Boston Consulting Group (BCG) and Global Fashion Agenda (GFA), 2017. sustainabilityportal. [Online] Available at: http://www.sustainabilityportal.net/blog/pulseofthefashionindustry [Accessed 10 2020].

The Good Shopping Guide, n.d. Ethical Home – Laundry Detergents. [Online] Available at: https://thegoodshoppingguide.com/ethical-laundry-detergents/ [Accessed 02 2021].

The conscious challenge, 2019. Water & Clothing. [Online] Available at: https://www.theconsciouschallenge.org/ecologicalfootprintbibleoverview/water-clothing [Accessed 11 2020].

The National Academies Press, 2020. Closing the Loop on the Plastics Dilemma: Proceedings of a Workshop–in Brief. [Online] Available at: https://www.nap.edu/read/25647/chapter/1 [Accessed 01 2021].

The World Bank, 2019. How much do our wardrobes cost to the environment?. [Online] Available at: https://www.worldbank.org/en/news/feature/2019/09/23/costo-moda-medio-ambiente [Accessed 01 2021].

THECONSCIOUSCHALLENGE, 2019. WATER & CLOTHING. [Online] Available at: https://www.theconsciouschallenge.org/ecologicalfootprintbibleoverview/water-clothing [Accessed 02 2021].

Trianni, A. & Cagno, E., 2012. Dealing with barriers to energy efficiency and SMEs: Some empirical evidences. [Online] Available at: https://www.researchgate.net/publication/265519052 Dealing with barriers to en ergy efficiency and SMEs Some empirical evidences [Accessed 10 2020].

UL LLC, n.d. The importance of chemical management for the circular economy. [Online] Available at: https://crs.ul.com/en/knowledge-center/importance-chemical-management-circular-economy/ [Accessed 01 2021].

UN-Water; FAO, 2014. United Nations. [Online] Available at: https://www.un.org/waterforlifedecade/scarcity.shtml [Accessed 10 2020].

UNIDO, WBG, GIZ, 2017. An International Framework For Eco-Industrial Parks. [Online] Available at: http://documents1.worldbank.org/curated/en/429091513840815462/pdf/122179-WP-PUBLIC-AnInternationalFrameworkforEcoIndustrialParks.pdf [Accessed 12 2020].

United Nations Conference on Environment and Development (UNCED), 1992. Report of the (UNCED). [Online] Available at: https://www.un.org/esa/dsd/agenda21/Agenda%2021.pdf [Accessed 12 2020].

United Nations Environment Programme-UNEP, 2011. The Chemicals in Products Project: Case Study of the Textiles Sector. [Online] Available at: http://www.health.gov.vc/health/images/PDF/cip textile case study report 21 feb 2011.pdf [Accessed 01 2021].

United Nations Environment Programme-UNEP, 2020. Sustainability and Circularity in the Textile Value Chain, Global Stocktaking. [Online] Available at: http://hdl.handle.net/20.500.11822/34184 [Accessed 01 2021].

United Nations Industrial Development Organization- UNIDO, 2020. Switch to circular economy value chains, Side Event at the World Circular Economy Forum.. [Online] Available at: https://www.unido.org/unido-at-WCEFonline [Accessed 01 2021].

United Nations Industrial Development Organization-UNIDO, 2019. ECO-INDUSTRIAL PARKS ACHIEVEMENTS AND KEY INSIGHTS FROM THE GLOBAL RECP PROGRAMME 2012 – 2018. [Online] Available at: https://www.unido.org/sites/default/files/files/2019-02/UNIDO EIP Achievements Publication Final 0.pdf [Accessed 12 2020].

United Nations, 2010. The human right to water and sanitation, Resolution adopted by the General Assembly. [Online] Available at: https://undocs.org/pdf?symbol=en/a/res/64/292 [Accessed 01 2021].

United Nations, 2019. UN launches drive to highlight environmental cost of staying fashionable, United Nations News, Climate and environment. [Online] Available at: https://news.un.org/en/story/2019/03/1035161 [Accessed 03 2021].

Vade, A., 2020. APPLICATION OF CHITOSAN IN TEXTILE. [Online] Available at: https://www.researchgate.net/publication/340902131 APPLICATION OF CHITOSAN IN TEXTILE [Accessed 01 2021].

Vadicherla, T. & Saravanan, D., 2017. Effect of Blend Ratio on the Quality Characteristics of Recycled Polyester/Cotton Blended Ring Spun Yarn. [Online] Available at: http://www.fibtex.lodz.pl/article1775.html [Accessed 01 2021].

Verma, S. & Gupta, G., 2017. Natural dyes and its applications: A brief review, INternational Journal or Research and Analytical Reviews, Volume 4, Issue 4.. [Online] Available at: http://www.ijrar.com/upload issue/ijrar issue 490.pdf [Accessed 02 2021].

Waring, R., Harris, R. & Mitchell, S., 2018. Plastic contamination of the food chain: A threat to human health?. [Online] Available at: https://www.maturitas.org/article/S0378-5122(18)30350-5/fulltext [Accessed 01 2021].

Wearesustainn, 2016. 5 Steps to Unveil Circular Economy-oriented Business Opportunities. [Online] Available at: http://www.wearesustainn.com/en/2016/05/5-steps-to-circular-economy-business-opportunities/ [Accessed 11 2020].

Well Dressed, 2006. The present and future sustainability of clothing and textiles. [Online] Available at: https://www.uselessgroup.org/files/well dressed.pdf [Accessed 11 2020].

Wilts, C. H. & Berg, H., 2017. Digitale Kreislaufwirtschaft : die digitale Transformation als Wegbereiter ressourcenschonender Stoffkreisläufe. [Online] Available at: https://epub.wupperinst.org/frontdoor/index/index/docId/6977 [Accessed 10 2020].

Wijkman, A. & Skånberg, K., 2020. The Circular Economy and Benefits for Society Jobs and Climate Clear Winners in an Economy Based on Renewable Energy and Resource Efficiency, A study report at the request of the Club of Rome with support from the MAVA Foundation. [Online] Available at: https://clubofrome.org/wp-content/uploads/2020/03/The-Circular-Economy-and-Benefits-for-Society.pdf [Accessed 02 2021].

Workman, D., 2020. T-shirt Exports by Country. [Online] Available at: http://www.worldstopexports.com/t-shirt-exports-by-country/ [Accessed 02 2021].

World Business Council for Sustainable Development (WBCSD), 2008.Sustainable consumption facts and trends. [Online] Available at: https://saiplatform.org/uploads/Modules/Library/WBCSD Sustainable Consumption web.pdf [Accessed 10 2020].

World Economic Forum in collaboration with the Ellen MacArthur Foundation and McKinsey & Company, 2014. Towards the Circular Economy: Accelerating the scale-up across global supply chains. [Online] Available at: http://www3.weforum.org/docs/WEF ENV TowardsCircularEconomy Report 2014.pdf [Accessed 11 2020].

World Economic Forum; Ellen MacArthur Foundation; McKinsey, 2016. The New Plastics Economy Rethinking the future of plastics. [Online] Available at: http://www3.weforum.org/docs/WEF The New Plastics Economy.pdf [Accessed 01 2021].

World wildlife, 2013. The Impact of a Cotton T-Shirt. [Online] Available at: https://www.worldwildlife.org/stories/the-impact-of-a-cotton-t-shirt [Accessed 10 2020].

WRAP - Waste and Resources Action Programme, n.d. Colouration - AirDye. [Online] Available at: https://ckh.wrap.org.uk/colouration/airDye?breadcrumb= [Accessed 02 2021].

WRAP, 2017. love your clothes. [Online] Available at: https://www.loveyourclothes.org.uk/about/what-love-your-clothes [Accessed 11 2020].

Wright, B., 2020. Pilot project to tackle plastic polybag waste in fashion industry. [Online] Available at: https://www.just-style.com/news/pilot-project-to-tackle-plastic-polybag-waste-in-fashion-industry id138182.aspx [Accessed 02 2021].

ZERO WASTE EUROP, 2017. 4 reasons why recycling is better than incineration BY MARCO GIACOMAZZI. [Online] Available at: https://zerowasteeurope.eu/2017/09/4-reasons-why-recycling-is-better-than-incineration/ [Accessed 02 2021].

Zest N Zeal, 2018. Natural Dye Green Clothes. [Online] Available at: https://www.youtube.com/watch?v=Ft0Kum4EUUU&t=5s [Accessed 02 2021].

Zubair, M., 2020. A Diagnostic Expert System for the Coloration of Textile Fiber Blends, A dissertation submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the degree of Doctor of Philosophy. [Online] Available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwinv-fpuJ7vAhVxwQIHHS4JCgEQFjABegQIAxAD&url=https%3A%2F%2Frepository.lib.ncsu.edu%2Fbitstream%2Fhandle%2F1840.20%2F37474%2Fetd.pdf%3Fsequence%3D1%26isAllowed%3Dy&usg=AOvVaw2JXChJCS5eJdvyiQZwIdv1 [Accessed 11 2020].

11. Declaration

I herewith declare that I have completed the present thesis by myself and without the use of any aids other than those listed. All passages that were taken either directly or mutatis mutandis from published and non-published sources, have been marked as such. The thesis has never been submitted to a different examination authority in the same or similar form.

Mönchengladbach, 08.03.2021 [redacted]

(Location and date) (Signature of the author)